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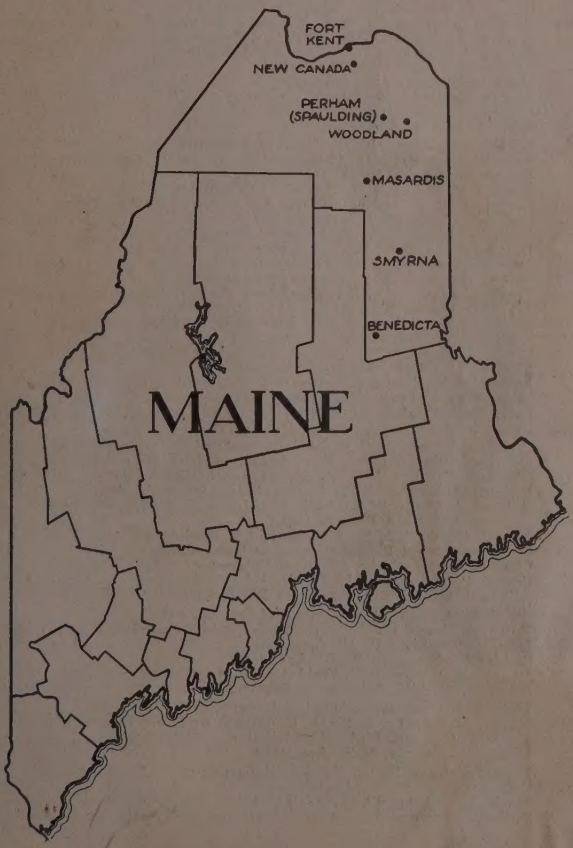
BULLETIN 403 SEPTEMBER, 1940

Aphids and Their Relation to the Field Transmission of Potato Virus Diseases in Northeastern Maine



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ACKNOWLEDGMENTS

The writer is indebted to a number of persons in connection with this study. In 1931, the early roguing was done by Dr. Donald Folsom, Plant Pathologist at the Maine Agricultural Experiment Station. Dr. Folsom has maintained a lively interest in the work and has assisted the project from time to time in numerous ways. Dr. Reiner Bonde, Associate Plant Pathologist at the Maine Station, with whom the writer has been associated in this work, supervised the roguing from 1933 on. Thanks are due to Dr. E. S. Schultz of the Bureau of Plant Industry, United States Department of Agriculture, and to Dr. Walter P. Raleigh, at one time associated with Dr. Schultz, both of whom have offered advice and criticism freely. The writer is indebted to Dr. Edith M. Patch, Entomologist Emeritus at the Maine Station, for the identification of aphids from time to time. He is indebted also to Mr. R. C. Dolloff, County Agent Leader, Extension Service, and to Mr. V. C. Beverly, County Agent of Aroostook County, for assistance in locating experimental plots on several occasions and for aid in securing the coöperation of the growers* on whose land much of this work was done.

The manuscript has been read by Dr. G. F. MacLeod of the University of California, by Dr. F. M. Blodgett of Cornell University, by B. B. Miner, Assistant Extension Editor, University of Maine, and by an editorial committee of the Maine Agricultural Experiment Station. For suggestions and criticisms offered, the writer is grateful.

* The coöperation of the following growers is gratefully acknowledged: Bean and Allen, A. Beaulieu, F. R. Corliss, Albert and David Daigle, Vennie Desjardins, Colby Estabrook, Waldo Holmquist, Dr. John H. Northrop, Ray Thompson, R. M. Robinson, Emil Rosen, Sherman Lumber Co., and Jasper Stevens.

BULLETIN 403

APHIDS AND THEIR RELATION TO THE FIELD TRANSMISSION OF POTATO VIRUS DISEASES IN NORTHEASTERN MAINE[1, 2]

G. W. SIMPSON

INTRODUCTION

Northern grown seed potatoes have, for many years, been given preference over seed produced locally in more southern areas *(4)*.[3] Intelligent growers, especially those located in southern New England and beyond, have learned by experience to depend on northern grown seed potatoes for the planting of fields which will present a more uniform appearance during the growing season and for higher yields at harvest time. They have learned also by experience that not all northern grown seed stocks can be depended upon to produce these desired results.

In 1914 Orton (*24*) published the results of his experiments and of his observations in the United States and in Europe. He called attention to the dangers inherent in continued planting of seed stocks including tubers harboring the viruses producing leaf roll, curly dwarf, or mosaic. At that time it was fairly well established that leaf roll was perpetuated through the tubers.

In 1915 Wortley *(44)* proved that mosaic also was perpetuated through the tubers. Proof was soon forthcoming of reduced yields from many types of virus diseases. Lack of uniformity in growth characteristics of fields planted with certain seed stocks

[1] This paper presents the entomological phases of a joint project conducted by the Departments of Plant Pathology and Entomology. Roguing has been done under the supervision of the Plant Pathology Department by Wesley Fletcher Porter, except as otherwise noted. The data secured in connection with early harvesting will be reported elsewhere by the department of Plant Pathology.

[2] In June, 1935, much of the information then available was presented to the Faculty of the Graduate School of Cornell University as a thesis in partial fulfillment of the requirements for the degree of Doctor of Philosophy. The title of the thesis was "Entomological Aspects of Seed Potato Production in Northern Maine."

[3] Italic numbers in parentheses refer to Literature Cited, p. 259.

also was associated, in many instances, with virus diseases. In 1919 evidence (*36*, p. 256) of the field transmission, by insects, of certain of the viruses producing these diseases was published. With this discovery came the first satisfactory answer to the question of why northern grown seed might be superior to any other.

Many attempts have been made to check the increase of virus diseases by hill selection. The failure of hill selection as a control measure was explained as the facts concerning spread of disease were established.

In 1921 tuber indexing (*1*) was shown to be of value in the location of satisfactory seed sources and in providing small supplies of seed which were quite free from disease and which could be multiplied.

Removing diseased plants from seed plots has been advocated by many workers and has met with varying success in different locations.

The basis for the present study is found in accumulated knowledge. An investigation along entomological lines was believed necessary to a better understanding of the seed situation in Aroostook County and to any attempt to improve seed stocks. In an endeavor to determine satisfactory situations as rapidly as possible, localities found to be unsuitable for the production of foundation seed were dropped from further consideration, even though they might have been of value in affording a more adequate explanation for the spread of virus diseases.

DEFINITIONS

Foundation Green Mountain seed stock. In this paper the use of this term is restricted to seed stocks of the Green Mountain variety containing few, if any, tubers infected with any virus other than that of latent mosaic (Smith's *Solanum virus* 1). In commercial usage in Aroostook County, the term is applied more widely and is commonly understood to include any seed stock of this variety that may, in favorable situations and in normal seasons, be propagated and certified for about three consecutive years. After three years, it is no longer possible, in most parts of Aroostook County, to grow such seed profitably for seed purposes because of spread of insect-borne diseases, chiefly mild mosaic (caused by

Smith's *Solanum virus* 3 in conjunction with *Solanum virus* 1) and in certain seasons, leaf roll (caused by *Solanum virus* 14).

Aphid migration. The aphid species considered in the following pages can overwinter in the egg stage. Infestation of potatoes and other secondary food plants in northeastern Maine is accomplished almost entirely by winged forms which develop on the respective overwintering host plants and then pass, typically by flight, to the potato or other summer hosts. Reinfestation of the overwintering host in the fall occurs in a similar manner. The term "migration" when used in this paper, is restricted to these phenomena.

Aphid dispersal. The immediate descendants of migrant aphids are able, at maturity, to establish additional colonies. While these descendants of spring migrants are unlikely to be winged, as the season progresses a larger number of winged forms may be expected in each succeeding generation, if conditions favor the normal development of the infestation. Both winged and wingless forms are known to move about *(6)* and in so doing produce an ever-widening infestation.

In this paper the term "dispersal" is restricted to the movement occurring within or between plantings of secondary host plants.

Mosaic. Where the term "mosaic" is used in this paper without any qualifying adjective it refers to the virus disease known as mild mosaic. The symptoms of this disease were described by Schultz and Folsom (*35,* p. 493). According to Smith's classification, mild mosaic is equivalent to the English crinkle and is caused by a combination of *Solanum virus* 1 and *Solanum virus* 3 (Potato viruses X and A) (*39,* p. 391).

Leaf roll. Where the term "leaf roll" is used in this paper it refers to the disease caused by *Solanum virus* 14 of K. M. Smith (*39,* p. 380).

Roguing. The detection, removal, and destruction of plants showing the symptoms of mosaic, of leaf roll, or of other virus diseases is termed roguing.

Green Mountain. The potato variety most extensively grown in Aroostook County is Green Mountain. This variety was used in the experimental work on which this paper is based. It was originated by H. O. Alexander, of Charlotte, Vermont, in 1878.

It is claimed to be a seedling resulting from a cross between Dunmore and Excelsior (*41,* p. 34).

Tuber unit planting. All of the experimental seed plots studied were planted by tuber units, that is, all seed pieces cut from a given tuber were planted in succession along the row before pieces from the next tuber were similarly placed.

Sources of seed. Except as otherwise noted, seed for each successive seed plot was obtained from the current seed plot at harvest time, that is, the seed stocks were replanted year after year.

REVIEW OF LITERATURE

The literature on potato virus diseases has become extensive during the past quarter century. Many different virus diseases of potato have been distinguished and described. The causal agents have received their share of attention. But, from the standpoint of an entomologist, few papers have appeared with a direct bearing on the production of virus-free seed potatoes[4] with particular reference to the relation of aphids to the field transmission of virus.

One of the early papers that gave an impetus to the study of the relationship of insects to virus diseases is that of McClintock and Smith *(19)* on a mosaic disease of spinach which is caused by *Cucumis virus* 1 of K. M. Smith (*39,* p. 52). The publication of Schultz *et al. (36)* opened the field of mosaic virus diseases of potato. Oortwijn Botjes *(23)* in Europe contributed similar information on leaf roll. In England, Davies *(6, 7, 10, 43)* studied the insects found on potatoes being grown for seed purposes in various areas in Wales and developed a method of predicting whether or not a given locality was favorable for seed production. In 1934 Schultz *et al, (31)* reported on their experiments with tuber-unit seed plots. Dykstra and Whitaker *(12)* reported on work with various insect vectors and reviewed the literature of this subject.

[4] Strictly speaking, this is possible only with such recently introduced varieties as Chippewa, Katahdin, Sebago, Earlaine, and Houma, since stocks of the older commercial varieties free from latent mosaics (*Solanum virus* 1) (*39,* p. 341) are not known.

Of the papers on potato virus diseases dealing with conditions in the field, only those by Davies, or of which Davies is a coauthor, have an entomological approach.

THE PROBLEM

The Practical Aspect

For local seed requirements, Maine must annually obtain about 2,500,000 bushels of seed potatoes. These potatoes may fall into two classes on the basis of quality because here potatoes planted for the production of table stock need not be as free from virus diseases of the mosaic type as is desirable in those planted for the production of certified seed. Spindle tuber [caused by *Solanum virus* 12 of K. M. Smith (*39*, p. 377)] is undesirable in any planting, and leaf roll [caused by *Solanum virus* 14 of K. M. Smith (*39*, p. 380)] is, at least potentially, a source of serious loss to any grower, especially to one raising Green Mountains.

The certified seed potato industry in northern Maine is dependent for its continuity on the yearly acquisition of foundation seed stocks sufficiently free from virus, and other diseases, so that the potatoes grown from this seed will pass State certification[5] requirements with little or no roguing of diseased plants.

About 10 per cent of the potato acreage in Maine is devoted each year to the production of certified seed. A large proportion of the seed actually certified by the State Department of Agriculture is intended for sale outside the State. Most of the remainder is used locally in the production of table stock, or, not finding an outlet as seed, is sold on the table stock market.

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[5] The Department of Agriculture of the State of Maine administers a seed potato inspection service charged with the duty of keeping the quality of the certified seed potatoes shipped from the State high enough to prevent undue loss to the southern buyer from causes inherent in the seed shipped. In practice, these causes include severe tuber defects, rots, rhizoctonia, scab, and virus diseases. The service provides two field inspections during the growing season and a third—an inspection of the tubers—at shipping time. Tolerances vary from year to year but tend to become somewhat more strict over a period of years. Seed potatoes meeting the requirements of the inspection service are "certified" by that authority and may be shipped under the "blue tag" which is tangible evidence to the buyer of that certification.

Between 6 and 7 per cent of the total crop produced in Maine finds its way into the certified seed trade. The acreage entered for State certification, acreage passed, and barrels[6] of potatoes shipped under the "blue tag" of the State certification service are shown in Table 1. The total production of potatoes in the United States, in Maine, and in Aroostook County is shown in Table 2.

Assuming that it requires 7 barrels of seed to plant an acre of potatoes, about 67,000 barrels[7] yearly are necessary to plant the acreage required to supply the present demand of the southern seed trade[8] for certified seed from Maine. At present some of this seed is raised in the State by a few growers who maintain seed plots to supply their own needs year after year. When funds have been available, considerable seed has been imported from Canada.

In most parts of Aroostook County, when diseased seed stock and aphids are present, dissemination of virus may usually be expected, even though measures are taken to prevent spread. In fact, the control measures applied in those areas of New Brunswick in which relatively successful attempts are made to maintain foundation Green Mountain seed stocks may be altogether ineffective in many parts of Aroostook County. A few locations in Aroostook County are known where foundation seed may be maintained by suitable efforts if isolation is such that field-to-field spread of virus does not occur. The seed stocks produced from year to year will not be of the same uniform quality but will vary in disease content depending on the amount of disease and the aphid population present during the preceding season.

THE SCIENTIFIC ASPECT

Infection of "healthy" hills. The infection of "healthy" potato stalks is believed to occur in several ways. These, listed in what is considered the order of decreasing importance, are:

1. By means of aphids dispersing from hills growing from seed pieces cut from tubers produced by plants that became diseased

[6] A barrel equals 11 pecks or 165 pounds of potatoes.

[7] Calculated on the basis of a 30 per cent shrink between harvest and planting time.

[8] Based on the average sales of certified seed for the years 1933-1937. Figures supplied by E. L. Newdick, Chief Div. of Plant Industry, State Dept. of Agr.

in a previous growing season. In well-conducted seed plots where roguing is practiced, the frequency with which spread of this nature may occur is greatly reduced because of the relation of roguing to the beginning and subsequent development of the aphid infestation (*14*, p. 196). In unrogued fields, diseased plants may be sources of infection from the time the plants become infested by aphids until they die or are killed by frost. Unfavorable growing conditions affect the physiology of the plant, tending to promote dispersal of the aphid population on that plant. If unfavorable growing conditions toward the end of the season are brought about by a lack of moisture, winged forms may be produced abundantly *(30)* thus favoring the spread of virus from field to field. Dispersal of aphids from certain diseased plants increases the chance of infection of neighboring healthy plants by wingless aphids and of hills at a greater distance by winged ones.

2. By aphids dispersing, from fields containing diseased plants, over varying distances not as yet definitely determined *(15)*.

It has been possible in recent years to study this phase of the problem because there have been available seed stocks free from certain of the virus diseases in question. It appears quite evident that the viruses producing mild mosaic and leaf roll do enter "healthy" stocks—presumably through the agency of dispersing aphids—at distances to upwards of a mile.

3. By aphids dispersing from hills inoculated during the current season.

When "healthy" plants are inoculated with the virus producing mild mosaic or that producing leaf roll, considerable time must usually elapse before the symptoms of these diseases become evident. Often no symptoms appear until the succeeding generation is grown. Such plants cannot, then, in most cases, be detected and removed. That they do serve on occasion as a source of infection has been found to be the case under special circumstances (*38*, p. 301). Under normal conditions with respect to the aphid infestation, it seems unlikely that this source of infection is as important as the preceding one.

4. By aphids dispersing from diseased plants growing from tubers surviving the winter in the soil.

This source of infection should present no difficulty in seed plots if a proper rotation is followed. Where continuous cropping

is practiced, trouble may be experienced from such sources of infection.

5. By insects other than aphids.

There is no evidence at present to support any statement to the effect that insects other than aphids are responsible for the field transmission of the viruses producing mild mosaic or leaf roll in Aroostook County. There are reports recorded from other sections of the country to the effect that the leaf roll virus may be transmitted by the potato leaf hopper *Empoasca fabae* Harris *(3)*. This insect is not normally abundant in the vicinity of Presque Isle and so has not received the attention in this connection that it may deserve.

6. By means other than insects.

Since mild mosaic is transmissible by juice inoculation (*34,* p. 49) and rubbing, it is entirely possible that, under favorable conditions, a small amount of transmission may occur as a result of vine injury in connection with spraying operations. It would certainly be a minor factor in rogued seed plots since roguing should be nearly finished by the time spraying is necessary.

Diffusion of virus from point of inoculation to the tuber. Virus introduced into a potato plant by aphids most frequently enters through the leaves or stems. A few instances are recorded where it entered through sprouts (*20,* p. 32; *33,* pp. 58-9; *40,* p. 7).

Under the conditions obtaining in Aroostook County, inoculation is believed to occur largely between the time the sprouts first break ground and the time the plants are killed by frost. Little information concerning the tissues involved in inoculation is available although phloem tissue is the most likely place. This belief is strengthened by certain studies of the feeding habits of aphids (*5,* p. 46; *12,* p. 328). Neither is much known of the way in which virus progresses from the point of inoculation to other parts of the plant. It is known that it progresses both upward and downward. Available experimental evidence indicates that it requires about 10 days for the virus to penetrate to the tubers (*34,* p. 97; *22,* p. 180).

Detection of causal agents in seed tubers. Attempts have been made to detect the causal agents of various potato virus diseases in the tubers while in storage. Thus far these efforts have met with little success. When such a method is found, it may be possible to devise a method for reducing the incidence of disease.

Even though it may not be entirely effective, such a method would be a valuable adjunct to other practices because, by eliminating diseased tubers before planting, roguing would be made easier and more effective or actually unnecessary. Considerable leaf roll may be eliminated from seed stocks grown in carefully rogued seed plots by discarding tubers showing net necrosis (*16*, p. 3) when the tubers are cut for planting. Net necrosis is not found in some varieties of potatoes even though they have been recently infected with leaf roll.

THE SCOPE OF THE EXPERIMENTAL WORK

The experimental work herein reported has been conducted in Aroostook County, Maine. The potato variety Green Mountain has been used exclusively in these experiments. Mild mosaic has been of chief concern although leaf roll has been taken into account wherever it appeared in the experimental plots. Such restriction of the field was felt to be advisable because, in the opinion of qualified observers (*31*, p. 2) in the area, mild mosaic in Green Mountains is the outstanding virus problem of the seed growers in Aroostook County. In some seasons leaf roll may result in much more evident loss, especially when any large amount of net necrosis develops in the tubers during the storage period.

Other virus diseases can be controlled, some of them more easily, by the methods used to prevent the spread of the virus producing mild mosaic. With other potato varieties, control measures are identical. Varietal resistance to mosaic or to leaf roll renders control measures more effective.

PROCEDURE

IDENTIFICATION OF INSECTS

At the beginning of the experimental work, it was assumed that plant lice,[9] or aphids, were responsible for most of the field

[9] *Myzus persicae* Sulz. The green peach aphid.
Myzus pseudosolani Theob. The foxglove aphid.
Macrosiphum solanifolii Ashm. The pink and green potato aphid.
Aphis abbreviata Patch. The buckthorn aphid.
See page 211 for discussion and names.

transmission of the viruses producing mosaic and leaf roll. Attempts to secure transmission of leaf roll and of mosaic with flea beetles[10] and Colorado potato beetles[11] have failed, and the results agree with those obtained in Oregon (*12*, p. 327) with insects other than aphids. General collections of insects have been made from time to time from various experimental plots.

The aphids, in many cases, especially during the first year, were identified by Dr. Edith M. Patch.

Aphids of doubtful identity were mounted on slides and compared with material determined by Dr. Patch. In the field, identification was often possible by sight aided, at times, by a 10x hand lens.

STUDY OF MIGRATION

In Maine, the usual overwintering hosts of the four potato aphids have been known for some time. The spring generations of the pink and green potato aphid and those of the buckthorn aphid can be found quite readily on their respective primary host plants. The foxglove aphid may, in certain locations, have found a host other than foxglove[12] acceptable. There is but one authenticated record for Aroostook County of specimens of the green peach aphid taken from an overwintering host. In this instance wild plum[13] served as an acceptable primary host. *Prunus virginiana* L. and *P. pennsylvanica* L. are common in Aroostook and are, at least, potential hosts for this aphid. Collections from both plants have been made in New Brunswick (*2*, p 184). Although some little time has been spent searching for other hosts, none has been found, nor has a second spring colony been found on wild plum. There is some evidence that the green peach aphid may be able to maintain itself through the storage period on tubers (*2*, p. 184). That it can maintain itself in greenhouses and on house plants is well known. In Wales the green peach aphid can maintain itself out-of-doors on various cruciferous plants (*39*, p. 540).

Because the aphid generations on potato have been of more

[10] *Epitrix cucumeris* Harris.
[11] *Leptinotarsa decemlineata* Say.
[12] *Digitalis purpurea* L.
[13] *Prunus nigra* Ait.

interest in connection with this project, little attention has been given to migration. Spring colonies of the pink and green potato aphid and of the buckthorn aphid have ordinarily been watched as a means of knowing when to expect to find migrant forms on potatoes. The establishment of summer colonies on potatoes has been given considerable study since this is the initial phase of the relationship between aphids and virus diseases. It usually results in little or no transmission of virus diseases except from one hill to another within the planting concerned. Little attention has been paid to the return migration of the aphids in the fall.

STUDY OF DISPERSAL

Two types of dispersal can be recognized in the dissemination of potato viruses. One is dispersal brought about by winged aphids. Such dispersal serves to extend the range of the aphid during the summer and is limited to numerous species of summer host plants. Certain factors influencing the development of winged forms have been presented recently by Schaefer *(30)*. While he was dealing with *Macrosiphum pisi,* there is no reason to believe that other species should react in a different way to similar stimuli. Once winged forms are produced, their dispersal will be determined by certain fairly well defined meteorological factors. Davies *(8, 9)* has made a careful study of these factors and has concluded that free flight of winged aphids will be stimulated by the following combination of factors: Temperature 65° or above; humidity 70 per cent or under; wind velocity not greater than about 5 miles per hour.

Wind velocity is often too great in Aroostook County to permit of free flight of aphids. There are periods, however, especially in the early morning and late afternoon, when wind velocity would favor flight. Stronger air currents frequently follow calm periods both in the morning and in the afternoon.

Winged aphids are believed to be responsible for most field-to-field transmission of virus. Since few winged dispersal forms are found before the latter part of August, it often happens that frost kills potatoes before much transmission of virus can occur. What transmission does take place may not result in tuber infection if the plants are killed before enough time has elapsed to permit penetration to the tubers of the virus concerned.

A second type of dispersal, much more limited as far as distance is concerned, but of much more frequent occurrence, is that brought about by wingless forms moving within plantings of potatoes.

In potatoes, dispersal of wingless forms may occur voluntarily or may be forced.

Davies *(6)* has studied the voluntary movement of aphids on potatoes. This study was largely concerned with the movement of wingless forms. It was found that more than three-quarters of the individuals observed had moved within 24 hours and all had left the leaf on which they were first observed within a week's time. The importance of this movement in the dissemination of viruses is emphasized by Davies.

When fields are not rogued and diseased plants remain growing throughout the season, repeated opportunities for transmission of virus occur. In rogued seed plots in Aroostook County, when planting has been done early in May, there is little danger from this source except in seasons when field-to-field spread of virus takes place. Additional spread within the plot may be brought about by wingless dispersal forms following introduction of the virus by winged aphids.

Field observations indicate that voluntary dispersal of wingless green peach aphids may bring about exceedingly heavy spread of the leaf roll virus (*38,* p. 300).

The mild mosaic virus does not appear to spread as rapidly in ordinary seasons as does leaf roll in seasons when green peach aphids are abundant.

Forced dispersal of aphids may be due to the passage of machinery, to the effect of rain or wind, or, in rogued fields, to the roguers themselves. There is reason to believe that many aphids are killed, or injured enough to make them incapable of transmitting disease, when forced dispersal occurs and that this phenomenon is relatively unimportant in the transmission of potato viruses within seed plots.

DEVELOPMENT OF THE APHID INFESTATION ON POTATOES

Davies *(10)* has outlined, for Wales, the establishment and subsequent development of the infestation of potatoes by the green peach aphid. Conditions in Wales are such that this aphid can

continue to exist on secondary host plants throughout the year.

In Aroostook County, all the potato-infesting aphids can overwinter out-of-doors in the egg stage. The establishment of an infestation on potatoes has been outlined by Patch *(28)*.

The development of the infestation, once established, depends on the interplay of meteorological factors and the parasites and predators that prey on aphids in this region.

While winged migrants begin to reach potatoes the latter part of June, the infestation is usually slight until the middle of July. By this time most of the nymphs deposited on potatoes by winged migrants are fully matured and beginning to produce young. The aphid index starts to rise and, in normal seasons, will increase throughout the first 3 weeks of August, reaching a maximum around August 20. A reduction, sometimes quite rapid, then occurs under the influence of a fungus that attacks aphids.

In 1937, a year in which widespread dissemination of the viruses producing leaf roll and rugose mosaic [*Solanum virus* 2 (Y virus) of K. M. Smith (*39*, p. 348)] occurred, the green peach aphid was not checked in August and the infestation continued to increase into September.

In Aroostook County, natural checks operate to prevent the development of aphid populations large enough to injure plants directly. Even with the large populations encountered in 1937, the only fields in which direct aphid injury was observed were known to have been overcropped.

ISOLATION OF SEED PLOTS

There is general agreement among those working with potato virus diseases that a seed plot should be isolated from commercial fields. All the available evidence indicates that the greater the distance of the seed plot from potential infection centers, the less disease is likely to enter from infection centers located at a distance from the plot. In the several experimental seed plots, isolation from infected potatoes has varied considerably—from a few yards to 5 miles.

At least 2 types of isolation are available to seed growers in Aroostook County. The most obvious is distance from other potatoes. This type of isolation is often expensive and difficult to

secure even on the outskirts of the intensively cultivated areas of Aroostook County. Effective distance is in part determined by the type of vegetation found between the seed plot and other potatoes. On many farms, open fields intervene. Much greater distances appear to be necessary, in such cases, to prevent field-to-field spread of virus than are required when forest growth separates the seed plot from other fields. A partial explanation is to be found in the manner in which aphids fly *(8, 9)*.

In Aroostook County, it is much easier to secure an isolated farm than to secure an isolated seed plot on any farm. A number of farms have been under observation in this connection for a number of seasons. Most of these have proven, in practice, to be well enough isolated to prevent farm-to-farm spread of virus. In no case studied, however, has it been possible to prevent field-to-field spread of the causal agents of mosaic and of leaf roll in certain seasons. Therefore, adequate isolation of the seed plot from other fields on the farm, if these fields contain any diseased plants, seems to be a necessary, but as yet unattained, condition for the maintenance of "healthy" seed stocks.

A second type of isolation that offers promise in the control of mild mosaic in Green Mountains is the use of large acreages of varieties resistant to this virus disease to provide isolation for a Green Mountain seed plot located near the center of the planting. No successful use has yet been made of this type of isolation because it is impossible at the present time to obtain stocks of varieties resistant to mild mosaic that are free from leaf roll. The resistant varieties are all of earlier maturity than Green Mountains and with leaf roll present this would, in many seasons, result in the transmission of leaf roll virus to the Green Mountains.

LOCATION OF EXPERIMENTAL PLOTS

In 1931 seed plots were located on the farms of interested growers through the assistance of the county agricultural agents and station colleagues. From observations made during that summer and the results obtained with these seed plots, it became apparent that the location of the plots with respect to the surrounding vegetation influenced the aphid infestation and also had a bearing on the total infestation and its development throughout the season. In subsequent seasons, experimental seed plots have been located

in various parts of Aroostook County[14] separated by as much as 120 miles, but all situated within an area less than 40 miles in width east to west.

An attempt has been made to include as many different kinds of situations as possible, from farms well isolated from other farms to those in intensively cultivated areas, from plots located in low, wooded sections to others in higher, cleared areas, and from some in the vicinity of swampy land to others in well-drained locations. In this way seed plots located differently, with respect to both primary and secondary aphid host plants, have been placed under observation.

APHID COUNTS

In studying aphid populations, counts were made at random throughout each plot. Three leaves of each plant counted were examined and a record made of the number, kind, and condition of any aphids found. Leaves selected for counting included a top, a middle, and a bottom leaf because there is considerable variation in the number of aphids of a given species depending on the location of the leaf on the plant (*28,* p. 21; *37,* p. 635).

While the actual number of counts made in a given instance was determined by the size of the plot and its shape, 100 plants (300 leaves) was sufficient to provide the desired information.

DETERMINING TIME OF DISSEMINATION OF MOSAIC

An important consideration in seed plot work is a knowledge of the time when dissemination of the viruses producing mosaic and leaf roll takes place. Knowledge of the facts involved has a bearing on recommendations for dates of planting and for roguing. Since other experiments being conducted by other workers on Aroostook Farm[15] were producing more detailed information on this point for a particular locality, no detailed experiment was undertaken. All diseased hills were removed from all experimental seed plots as soon as detected, and so only a few hills could be har-

[14] Between about 67° 45′ and 70° west longitude; 45° 30′ and 47° 30′ north latitude. The cultivated area of the county does not extend much beyond 68° 45′ west longitude.

[15] The experimental farm owned and operated by the Maine Agricultural Experiment Station and located in the town of Presque Isle.

vested adjacent to diseased hills removed toward the end of the season.

In harvesting tubers for this study, hills were chosen at either end of the diseased tuber unit removed. Two hills were thus taken in the row from which the diseased hills had been removed. From the rows to the right and to the left of this row, 8 hills were harvested, 4 from each row. These were chosen so that they were as nearly as possible opposite the area from which the diseased hills had been removed. Thus those hills most likely to become infected were harvested (*34,* p. 103). Hill-to-hill spread of the viruses producing mosaic and leaf roll is believed to be a major threat to successful seed plot work when isolation from sources of infection in other plantings is adequate to prevent field-to-field spread of virus. The harvesting of these hills served also to reduce the number of mosaic tubers planted in succeeding seed plots (Tables 7, 15, 23, 28, 33, 39, 48).

The lots harvested each fall from the various experimental seed plots were bagged separately and planted on Aroostook Farm the following spring. As will be seen from the various tables presenting these data, considerable variation in hill-to-hill spread was found from year to year and from plot to plot (Tables 7, 15, 23, 28, 33, 39, 48).

SEED SELECTION

Methods of selecting seed for subsequent seed plots. Except as indicated, seed was replanted year after year in each seed plot. In 1931 and 1932, seed was selected for size from the bins in which the seed from the previous seed plots had been stored. In 1933 selection of seed was practiced on a small scale at Masardis. In 1934 and the years following, early harvesting has been practiced in all plots. Of the plots described, only those at Masardis have been planted with early harvested seed. Both early harvested and late harvested seed have been used in other cases, largely because a comparison between the two methods of selecting seed was desired. In the case of the foundation seed farm in Masardis, the late harvested seed was being planted in commercial fields and a check was thus possible without using anything but early harvested seed in the seed plot.

When more than 1 per cent of the plants in a seed plot are diseased, it is often difficult to select an area, or areas, large enough to provide early harvested seed adequate in amount to plant the next year's seed plot. Unless these areas are selected with a view to avoiding locations from which diseased units have been removed, there is danger of selecting hills containing tubers harboring virus as a result of its spread from hill to hill before roguing is completed.

A number of investigators have found the practice of hill selection to be of little value in reducing the number of diseased tubers in a seed stock (*13,* p. 180). If the field in which hill selections are made has not been rogued, this practice will be of even less practical value than it is in rogued fields, especially in seasons when hill-to-hill spread of virus takes place.

Experiments have shown that, except when insects are unusually abundant, virus transmission under Aroostook conditions takes place from row to row and more especially from hill to hill within the row (*17,* p. 58). In fields that contain but few diseased plants, transmission of the causal agents of mosaic and leaf roll (*21,* p. 567) seems most likely to be to adjacent hills in the same row. With sources of infection strictly limited, fewer winged aphids become infected, and what transmission of virus takes place is more likely to be accomplished by wingless aphids.

Taking these facts into consideration, it seemed logical that fewer diseased tubers would be included among those planted the following year in the seed plot if a judicious selection were made of the area within the seed plot from which those tubers were harvested.

Selecting seed for subsequent seed plots at Masardis. At Masardis, during 1931 and 1932, seed for the next seed plot was not selected by the grower in any way except for size and shape. It did come from a definite part of the seed plot and in both years was stored over the winter in barrels. No selection was made of the location in the seed plot from which tubers were harvested.

With the importation of seed for the 1933 seed plot, a new method of selecting seed was adopted. This method involved the early harvesting[16] of enough seed for a part of the 1934 seed plot.

[16] Suggested by Dr. Walter P. Raleigh, then Associate Pathologist, Bureau of Plant Industry, U. S. Department of Agriculture, as a result of experimental work which was based on observations made earlier by Schultz and Folsom (*32,* p. 332; *34,* p. 104).

The early harvesting was done after the middle of August when roguing for mosaic and leaf roll had been completed. It was thus possible to select an area in the seed plot from which no diseased plants had been removed. Since most hill-to-hill spread of the viruses producing mosaic and leaf roll is to hills adjacent to diseased plants, it was possible to eliminate many diseased tubers by avoiding, in securing seed for another year's seed plot, all hills in the immediate vicinity of diseased hills previously removed. One may or may not avoid, by this procedure, hills infected by winged migrant or dispersal forms.

Before pulling the tops in the area selected for early harvesting, all stalks in each hill were carefully examined to make certain that there was no disease evident in the foliage or growth character of the plants. If any such were found, all of the hills in the immediate vicinity in the row and in adjacent rows were discarded. After the tops had been pulled, 10 days were allowed to pass before the tubers were dug. This permitted the tubers to harden up and prevented peeling. As soon as harvested, the tubers were placed in barrels where they remained until spring, except for a short period, during which they were treated for the control of externally borne diseases.

This procedure has been followed each year since 1933 and has proved to be important in reducing the number of tubers having mosaic or leaf roll in the strain of Green Mountains being maintained on this farm. Beginning in 1934 enough seed has been early harvested each year to plant the entire seed plot the following season. The rest of the seed plot has been harvested at the usual time and has been used to plant the commercial fields on this farm.

Rogueing

Rogueing, when the seed plot has been planted early in a favorable location, aids in the elimination of mosaic and of leaf roll from seed stocks of Green Mountains. In late-planted seed plots, without effective isolation, rogueing will not eliminate these diseases.

Rogueing is not successful unless the seed plot is isolated so that there is no field-to-field spread of virus.

Early planting is, after adequate isolation, the most important consideration. With early planting rogueing can be done when the aphid index is low. If diseased plants are not removed before

they become infested, they may serve as sources of infection. When apparently healthy hills become infected, they may serve in August as centers of secondary spread. It is usually impossible to detect them until the next season.

If but few plants show symptoms of disease and can be removed early in July, roguing can become a satisfactory practice; if not, it can be of little value beyond preventing the further propagation of previously infected tuber lines.

Many seed growers in the past have rogued carelessly. Diseased plants have frequently been pulled and left in the row to wither, thus forcing dispersal to adjacent plants of any aphids that may have been present. Seed pieces have been allowed to remain in the row only to sprout again. The resulting plants, while not often producing marketable tubers, certainly have been potential sources of infection, more dangerous perhaps than the plants that had been pulled, because of their age in relation to more mature adjacent hills. Tops have been carried along the row under the arm only to be dropped in piles at the ends of the field thus effectively concentrating those aphids most likely to be infected and capable of transmitting disease.

The roguing technique finally adopted as best suited to the needs of this study has been described in Extension Bulletin 259 entitled "Seed Potatoes for Growers of Table Stock" and published by the Extension Service of the University of Maine.

POTATO APHIDS

Important Influences on the Occurrence of Different Species of Aphids Involved in the Spread of Mild Mosaic

An interesting fact brought out by this study is that there are some apparent differences in the distribution of the four potato aphids within Aroostook County. This uneven distribution of aphids appears to be correlated with the distribution of the respective winter host plants.

Buckthorn appears to be associated with damp or wet situations. Potato fields in these low areas are most likely to be infested with the buckthorn aphid. It has been apparent during the past

few years that this species often has been absent from the plots located on rather high land. It is true also that plots located at some distance from buckthorn have been infested later in the season than plots located nearer the winter host of this species. The distance of the seed plot from buckthorn thus helps to determine the total number of aphids that may be produced in the seed plot which is, of course, also related to the length of time that the aphids are present on the potato plant.

Wild and escaped roses are quite abundant throughout Aroostook County and neighboring New Brunswick, so it is not surprising that the pink and green potato aphid is found in every locality that has been under observation. Wide fluctuations have occurred in its abundance from year to year but in no case has it been entirely absent from the experimental plots.

The green peach aphid seems to fall in the same category as the buckthorn aphid as to prevalence. Little is known of the distribution of its winter host or of the ways in which it can maintain itself through the winter. It is found at some time during the summer, in most potato fields.

The distribution of the foxglove aphid and of its known winter host have not been determined.

APHIDS ON POTATOES AS A HOST

There is no assurance that the date on which an aphid is first recorded from a plot is the date on which aphids first migrate to that plot. The date of record is an indication of the time when aphids were sufficiently numerous to be found by random sampling of the plants in the plot. Often, when an immature aphid is found, its stage of development will be a clue to the date on which it may have been deposited. Random sampling should be adequate to detect the first generation on potato, so that the dates recorded would not be more than 10 days later than the first arrival of aphids in the plots. Many factors may affect the date of appearance of aphids in a plot. Probably the most important point in this connection is the location of the winter host of the aphid species in relation to the plot. This seems to be especially true of the buckthorn aphid but not of the pink and green potato aphid.

Surprisingly little consideration has been given to the aphid

XXI, 125; XXV, 389

population on potatoes. Two papers by Davies *(6, 10)* are of especial interest. Among other considerations he has stressed the date of maximum infestation. He has made a distinction between the effect produced in those cases where an aphid population is reproducing and the effect produced where the infestation is augmented by winged forms from outside sources. In determining the date of maximum infestation in the present project, counts were made of the aphids on representative leaves in each experimental plot. Since the number of counts made in each plot varied with the size of the plot and was not based on a count of a definite number of leaves per plot, except in recent seasons, the figures obtained have been reduced to a common basis which indicates the percentage of infested leaves or the average number of aphids per 100 leaves (Davies' index figure). Counts have usually been made as late in the season as the condition of the foliage permitted.

In these studies the date of maximum infestation has usually occurred in August and most frequently during the latter half of the month. In a season especially favorable for aphids, it may come in September. It would seem evident that in isolated, rogued plots in Aroostook County this date is significant only when plants infected earlier in the season serve as centers of infection or if masking of foliage symptoms is general. In isolated, rogued seed plots, the date of initial infestation is of more importance. If a seed plot is so situated that aphids may disperse to it from fields containing diseased plants, the date of maximum infestation for the locality may be of importance, for it is unusual to find many winged dispersal forms until after this date. In unrogued fields the date is of considerable importance from a scientific standpoint for it is at this time that the greatest movement of the aphid population within the crop is taking place.

The intensity of an aphid infestation depends on several factors. The date of migration is important. Of more importance from the standpoint of individual seed plots is the date of the establishment of the aphid infestation. The infestation of a seed plot may be established by dispersing aphids rather than by migrating individuals if the plot is far enough from the winter hosts. Such a situation would be ideal from the standpoint of a seed plot, other things being equal, for it would mean that aphids would be of little importance because roguing could be accomplished before the infestation had started to develop. But if the dispersal forms come

from other potato fields rather than from other summer hosts, virus may be brought into the seed plot.

The evidence thus far obtained all points to the fact that the aphid population is far from stationary under normal conditions *(6)*. Dispersal may occur as a result of disturbing the plants, as in spraying or roguing. Under various conditions *(30)* aphids produce winged individuals. These winged forms are largely responsible for the summer dispersal of the species over considerable distances. Potentially, they are important from the standpoint of the transmission of potato viruses.

Apparently no evidence exists at present to show that an aphid which is capable of transmitting the virus of mild mosaic can produce offspring capable of transmitting the disease without first feeding on infected plants. Ability to infect a "healthy" potato plant is apparently limited to those aphids that have fed on diseased plants under certain conditions.

DATE OF PLANTING AND APHID INFESTATION

Seed plots planted as early as possible in the spring are likely to become infested with aphids before plots planted later. All of the experimental plots that have been planted in May have been infested before the middle of July and aphids have frequently been found earlier (Table 3). The plots planted in June, however, have, with 2 exceptions, been found to be infested after the middle of July or, in some cases, not until August. Infestation in the majority of such cases is not brought about by spring migrants but by dispersal forms. Since potatoes are the most numerous of secondary summer host plants, most, if not all, dispersal forms come from potatoes. In many cases these winged dispersing aphids carry virus.

Late planting, although it may prevent early aphid infestation, is undesirable from other standpoints and has proved in practice to be conducive to poorer seed than can be obtained from earlier planting, if other practices are comparable.

From the standpoint of aphid infestation alone, the date of planting is an important consideration. From the standpoint of producing seed as free as possible from mosaic and leaf roll, it is more important to be able to rogue early. In areas where much diseased seed is planted, it is of the utmost importance that the seed

plot mature early, thus reducing the chance that dispersal forms may introduce virus toward the end of the season.

APHIDS IN RELATION TO THE VIRUS DISEASES OF POTATOES

Since it was assumed in projecting the present investigations that aphids were capable of transmitting the mild mosaic virus (*12,* p. 326; *35,* p. 509; *36,* p. 256-7), no justification of this phase of the work has been attempted.

There are four species of aphids found more or less commonly on potatoes in Aroostook County. These are the foxglove aphid (*Myzus pseudosolani* Theob.) *(29),* the pink and green potato aphid (*Macrosiphum solanifolii* Ashm,[17]) *(26),* the buckthorn aphid (*Aphis abbreviata* Patch[18]) *(27),* and the green peach aphid (*Myzus persicae* Sulz.) *(28).*

The role of the foxglove aphid in the dissemination of the mild mosaic virus is at present uncertain. It is known to be a vector, or carrier, of leaf roll (*39,* p. 543). It appears to vary greatly in numbers from season to season and has been found only in restricted areas in Aroostook County. This may be due to the fact that its known winter host, foxglove (*Digitalis purpurea* L.), is rather rare and of restricted local occurrence in the county.

The only evidence concerning the influence of the foxglove aphid on seed potato production in the writer's experience is the fact that this aphid was present during 2 seasons in the plots which are considered to have been as successful as any of those under experiment.

The pink and green potato aphid is found in all parts of Aroostook County and adjacent areas. In favorable seasons it is the dominant species in point of numbers. Its winter host is rose, of which there are many plants present in Aroostook County, both cultivated and wild. Escaped roses are the most important sources of the yearly infestation on potatoes in the intensively cultivated areas, while the native roses appear to be the source of infestation in more recently cleared areas. Occasionally, but rarely, the pink and green potato aphid has been known to increase to such an extent that potato plants have been injured. The increase of this

[17] (= *M. gei* Koch)

[18] Probably not synonymous with *A. rhamni* Boyer (*18,* p. 379-80).

aphid is usually checked in Aroostook County by natural enemies and fungus diseases before the plants are materially injured. Since there are large acreages of potatoes available at the time of migration, it is not surprising that fields are likely to be heavily infested by this species (*25,* p. 205). Its ability to transmit mild mosaic is established (*13,* p. 169; *36,* p. 256-7), although Smith (*39,* p. 533) feels that aside from the dissemination of spindle tuber the aphid's relation to the dissemination of potato diseases is still questionable.

The buckthorn aphid has, over the period of this study, been the dominant aphid species in point of numbers in plots located close to its winter host. At greater distances it is of less importance and may, in some cases, be entirely absent. Coming to the potato very early in the season as it does, this insect multiplies rapidly in favorable seasons until more than 1,000 individuals frequently have been found on 1 potato leaf. The buckthorn aphid prefers the lower part of the potato plant as a feeding place. When the population is so large that crowding occurs on this part of the plant, some aphids may be found on every leaf although the majority of the aphids will still be below the middle of the plant.

The overwintering hosts of the buckthorn aphid are species of the genus *Rhamnus, R. alnifolia* L'Her, and *R. cathartica* L. in Maine, the former of which, at least, is found in low areas, often growing in places more or less flooded at certain times of the year. The life history of this insect has been reported in detail by Patch in Maine Agricultural Experiment Station Bulletin 323 *(28).* As noted there, this species has normally migrated by the last week in June. For this reason it is potentially dangerous from the standpoint of the transmission of the causal agents of potato virus diseases. Its ability to transmit the virus producing mild mosaic is established (*35,* p. 518), although Smith (*39,* p. 353) questions its role as a vector of potato virus diseases in England. If, as recently suggested (*18,* pp. 379-80) *A. abbreviata* is not a synonym of *A. rhamni,* the conflicting reports may be easily explained.

The buckthorn aphid tends to increase in numbers as the season advances, producing winged dispersal forms, and, as conditions become crowded or the plant becomes less attractive as a source of food, dispersing in the wingless form as well. Transmission of the causal agents of virus diseases is favored by the preference of this aphid for a position toward the base of the plant,

since the lower leaves of the plant tend to die from various causes before the plant as a whole is dead. When this occurs, the aphids disperse and are almost as likely to crawl onto the interlaced leaves of a neighboring plant, according to the writer's observations, as they are to seek a new position on the same plant.

By the first week in September, the buckthorn aphid produces fall migrants abundantly and the potato is deserted by it.

The green peach aphid is generally admitted to be the most effective vector of potato viruses, as well as of many other diseases of virus origin in other hosts (*39,* p. 541). The species is found in most parts of Aroostook County.

The only known overwintering host of the green peach aphid in Aroostook County is a wild plum (*Prunus nigra* Ait.), which is not known to be especially abundant in the county. This would lead one to feel that there may be other plants serving as overwintering hosts, as is known to be the case in Wales (*10,* pp. 47-8). It is likely also that the insect may pass the winter on house plants or in greenhouses and go to the potato fields during the summer. It usually remains on the potato until the plants are killed by frost or die naturally. This fact is important in connection with the dissemination of the virus producing mild mosaic and even more so in the case of that producing leaf roll when late season transmission of these viruses can result in tuber infection.

The green peach aphid seeks locations toward the base of the potato plant, very seldom being found above the middle. This species appears to increase in numbers slowly, but rather steadily. Much more rapid increase has been experienced in seasons when the temperature has been above normal. Infestations seldom approach in intensity those achieved by the pink and green potato aphid or even by the buckthorn aphid in favorable situations. The green peach aphid is found almost everywhere throughout the county by the end of the season, if not earlier.

The green peach aphid appears to be, potentially at least, the most effective vector of virus that the grower of foundation stock must consider. However, due to certain peculiarities in its behavior, it may be successfully circumvented even in seasons when it is abnormally abundant. The aphid comes to seed plots in Aroostook County at a somewhat later date than the other species concerned. A grower should find it possible to complete a second or third roguing before the green peach aphid is present in sufficient

numbers to effect much transmission of virus within the plot. Assuming that the aphids that come to the plot are not infective, this would be especially true if the disease content of the seed stock planted is low.

The writer considers the green peach aphid to be of importance in the dissemination of mild mosaic in unrogued stock. Phenomenal increase in mosaic in one season under special conditions has been reported in the literature (*31*, p. 24). It is recorded that in unrogued stock most spread takes place after the first of August (*34*, p. 97, p. 104). Both facts seem best explained on the assumption that the green peach aphid was present during these seasons and at that time of year. The fact that this aphid is the last to leave the potato in the fall should not be overlooked in this connection. A significant fact has been disclosed by a numerical study of the aphid populations in the various experimental plots indicating that the green peach aphid is much more abundant in the years when the greatest spread of virus has been encountered.

OTHER ENTOMOLOGICAL CONSIDERATIONS

The information accumulated during the course of this study leads to certain conclusions concerning the role played by 3 of the 4 aphid species that commonly infest potatoes in Aroostook County.

Where seed plots have been inadequately isolated from fields containing diseased plants, it has been impossible to eliminate mosaic or leaf roll. In several instances diseases of types not previously present in the seed plots have entered, providing ample evidence of the spread, from a distance, of the viruses producing these diseases. While the evidence is not so clear cut in many other cases, it seems likely that the causal agents of both mosaic and leaf roll also entered from time to time. In certain cases, secondary spread from recently infected plants increased the number of diseased tubers found when the seed stock was replanted.

Observations have shown that marked increase in the number of diseased tubers present in a seed stock occurred only in late planted plots or in years following a season when the aphid index reached a high level.

In connection with late planted plots, it has been observed that increases in the number of diseased tubers have been associ-

ated with the early maturity of diseased plants in nearby fields—usually planted earlier than the seed plots—and with increases in the number of winged aphids observed in the plots, especially during August.

In certain plots (Woodland, Spaulding) where no evidence has been obtained of field-to-field spread of the viruses producing mosaic and leaf roll, but where roguing has not been effective in eliminating either of these two diseases, it has been observed that the buckthorn aphid has been present early in appreciable numbers. Spread of the mosaic virus has evidently occurred before roguing could be completed. At Spaulding, this state of affairs was, in part, due to delayed planting of the seed plots.

Of the 14 locations where seed plots have been established for 2 or more years during the course of this study, only 2 have proved to be successful centers for the propagation of foundation seed.

In the case of one of the outstandingly successful plot locations (Benedicta), the buckthorn aphid was not observed in 1931 and was not found in the seed plots until August in 1932 or 1933. The pink and green potato aphid has been abundant every year, although in 1933 and again in 1934 the initial infestation of the seed plots was delayed somewhat. The green peach aphid, while present, did not infest the plants in the seed plots until late in the season. It was probably not a factor in this location until 1937 when it brought about considerable transmission of the leaf roll virus. The foxglove aphid, although observed in 1933 and 1934, does not appear to have affected the results obtained here. It is recognized in Europe as an efficient vector of the leaf roll virus (*39*, p. 543).

The entomological factors influencing results in this location were favorable. The buckthorn aphid did not effect transmission of the mosaic virus before plants showing symptoms of this disease could be removed, because it was not present early in the season during the 2 years when this seed plot was being cleaned up. The other species of aphids came too late to cause transmission of the viruses producing mosaic and leaf roll except as they brought them from other fields on the farm. So little field-to-field transmission of virus occurred in 1932 and 1933 that it proved possible, in 1933, to select seed that was not contaminated with mosaic and that contained but 4 tubers harboring the leaf roll virus.

The entomological factors encountered at the second successful center (Masardis) differed materially from those found at Benedicta. With the exception of 1936, buckthorn aphids have been found as early as the pink and green potato aphid. The green peach aphid has usually been found at a later date. As far as these conditions go, they do not differ appreciably from those found at several of the unsuccessful centers. In the first 3 seasons, little success was attained. When early planting became possible, more successful results were obtained and with the practice of early harvesting came elimination of both leaf roll and mosaic. Inadequate isolation from commercial tuber-unit fields on the same farm resulted in the reintroduction of both leaf roll and mosaic in 1937, indicating that there is nothing peculiar about the insect situation in this location that contributed to the fairly successful results obtained here. Successful handling of seed stocks at Masardis is to be attributed, in large measure, to the opportunity afforded, in the selection of seed, to avoid chance infections by aphids more successfully than was possible in other localities. An excellent seed stock at the start contributed materially to the results obtained.

As has been suggested by Davies and Whitehead (*11*, p. 555), the aphid population of a potato field may influence the spread of virus in at least 2 ways. If aphids come to potatoes from diseased hills or from other virus infected plants outside the field, they may infect relatively few plants among those within the field. If the aphids come from primary host plants, they are apparently noninfective. If the field to which the aphids come is free from diseased potatoes, the final results may be widely divergent, depending on the subsequent development of the aphid population. In the first case a high aphid index at the time of maximum infestation would lead one to expect considerable spread of virus. In the second case, a high aphid index at the time of maximum infestation would be of no consequence and one would expect the seed to be as free from virus the next year as it was when planted.

If the field to which the aphids come contains plants showing the symptoms of disease, the result in both cases is likely to be much the same. There will almost invariably be spread of virus. It is likely that there will be a higher percentage of diseased plants among the progeny growing from seed produced in the field to which infected aphids come than among that of the other field. The increase in the percentage of the plants showing symptoms of

disease will be determined largely by the movement of the aphids within the crop; both that of the winged forms that come to the fields and that of the progeny of these winged females. In these cases the aphid index at the time of maximum aphid infestation is of importance.

From a practical standpoint, there are probably few fields of potatoes in which no plant shows symptoms of any virus disease. Careful roguing early in the season can eliminate diseased hills. Whether or not this will prevent spread of virus depends on when aphids first come to the field and how numerous they are and whether or not they are infected when they arrive.

If an attempt is made to predict spread of virus, it appears to be necessary to know whether or not any diseased plants are present in a field; whether or not aphids can reach the field from infected plants at a distance; the time of the initial infestation and its intensity; and the subsequent development of the aphid population. This information is likely to be available only for individual fields. The time consumed in obtaining the necessary information may be more valuable than the prediction.

RESULTS OF EXPERIMENTS IN PARTICULAR LOCATIONS

Fort Kent

Some 60 miles north of Presque Isle along the Canadian border just south of the St. John River, in an area of small farms not exclusively devoted to potatoes, an experimental seed plot was established in 1931. The spot selected for the seed plot lies along the Bangor and Aroostook Railroad right-of-way. It was on the northern slope of a hill and had been recently cleared. The land sloped rather sharply toward the track from which it was separated by several yards of uncleared land. The plot was surrounded by woods. It was perhaps three-quarters of a mile from other potatoes. The soil was rather rocky but produced a good crop. The soil type was not that considered the best for potato production in this region.

1931. The seed planted in 1931 was relatively free from the viruses producing mosaic and leaf roll (Table 4), having been

purchased from a foundation seed grower in Prince Edward Island. The plot had been newly plowed and the planting had been done after most commercial planting in the area had been finished. Due to the nature of the terrain, the fertilizer distribution was not uniform and some uneven growth of the potato plants was encountered. The plot was dusted with hand machines and control of the late blight fungus was inadequate.

The last of the plants showing symptoms of mosaic and leaf roll were not removed until rather late in the season. The aphid index, on the basis of limited observations, was not, however, excessive by the time roguing was finished (Fig. 1).

About the middle of August, an examination was made of fields in the vicinity of the seed plot. A situation very different from that in the seed plot was found in a field some three-quarters of a mile west along the railroad right-of-way. Being the field nearest the seed plot, conditions were noted carefully. Plants showing the symptoms of crinkle, mild, and rugose mosaic were very evident. A small number of leaf roll plants also were present. Fully 85 per cent of the plants in the field showed symptoms of disease. The area of this field was somewhat more than an acre. Pink and green potato aphids were very numerous and included many winged forms. Green peach aphids were found on all lower leaves examined. Winged forms of this species also were present to a small extent. The diseased plants were in an unthrifty condition due, in part, to the feeding of the aphids.

The seed plot was visited on July 2 and again on July 7 but it was not until July 14 that pink and green potato aphids were found. Only a few were seen and many of these were immature forms, indicating that they had not been present on potato for any length of time. On July 22 the combined aphid index was calculated to be but 28.9. By the end of the month the pink and green potato aphid was being attacked by a fungus, while the buckthorn aphid had increased its numbers slightly (Table 6).

No green peach aphids were observed in the seed plot during 1931, probably because observations were not made after roguing was finished. They were found, as early as July 24, in other fields in the vicinity and in considerable numbers in at least one of these.

By August 11 the combined aphid index reached 66.7, the highest point recorded during the season. Late blight became

prevalent shortly afterward, and the plants died somewhat earlier than otherwise would have been the case.

Hills adjacent to mosaic units removed from the seed plot were harvested and these tubers planted in 1932. Some spread of the virus producing mosaic took place (Table 7). All of the diseased tubers produced plants that were recorded as having the symptoms of mild mosaic.

1932. Seed for the 1932 seed plot was picked, in the spring of 1932, from a bin in which the crop from the 1931 seed plot had been stored, being unselected except for size and shape. It was planted, after commercial plantings in this area, in a plot nearer to commercial fields than was the 1931 seed plot.

The first aphid was noted in this plot on June 25 when, by chance, a winged pink and green potato aphid was noted alighting on the plot. Green peach aphids and buckthorn aphids were first observed on July 24. Conditions continued to be favorable for the development of the green peach aphid and its numbers eventually exceeded those of the other two aphids combined, a circumstance as yet unrecorded in any other instance.

On August 16, 93 per cent of the leaves examined were infested. During the next 10 days, a fungus brought about a slight reduction in the infestation. Winged forms of the pink and green potato aphid and of the buckthorn aphid were present August 26 (Table 6).

In spite of the low incidence of disease in the seed stock imported for the 1931 seed plot, the amount of disease present in 1932 (Table 4) was excessive. That it was largely crinkle mosaic, a mosaic disease not present in the seed plot in 1931 but found in the next field, indicates that roguing was not as ineffective as it might appear to have been but that the isolation of the plot was inadequate to prevent field-to-field spread of the virus producing this disease.

1933. With so many diseased plants present and the combined aphid index reaching the point it did (Table 6), it is not surprising that the following year adequate counts in commercial fields planted with seed from the 1932 seed plot indicated that in excess of 15 per cent of the plants showed symptoms of mild or of crinkle mosaic.

The seed plots at Fort Kent were located in an area where it was not unusual, at that time, to find fields in which 90 per cent

or more of the plants were diseased. Observations made at various places in the region indicate that the green peach aphid is found in most fields and in greater numbers than in other sections of Aroostook County where similar observations have been made.

With so many diseased potatoes growing in this area and with so many diseased plants dying before healthy ones, it is not surprising that, when aphids become numerous, disease should enter seed plots not well isolated from the diseased fields. Late planting of the experimental seed plots at Fort Kent certainly did not improve the situation.

This locality was not studied after the close of the 1932 growing season.

CONCLUSIONS ON THE EXPERIMENTAL RESULTS OBTAINED AT FORT KENT

The record indicates that this was an unsuccessful center.

The only favorable factor in this experiment was found in the quality of the seed originally planted.

Unfavorable factors included planting of the seed plot following the planting of commercial fields in the area; inability to complete roguing before plant lice were present; isolation inadequate to prevent field-to-field transmission of virus; and, of most importance, seriously diseased seed stocks present throughout the area.

NEW CANADA

As a result of the experience gained in 1931 and 1932 at Fort Kent, a new location in the same area was chosen for a seed plot in 1933. The seed plots at Fort Kent had been at the level of the river and surrounded by woods. The location selected in New Canada—some 10 miles east and 3 miles south of the Fort Kent seed plots—was at a higher elevation and at a considerable distance from woods.

The soil was somewhat rocky and had been overcropped, but not enough to interfere seriously with the growth characteristics of the plants.

With the exception of 1934, seed plots at New Canada have been planted rather late in the season (Table 8). In most instances

considerable commercial planting in the area had been finished by the time the seed plots were started. This fact has doubtless contributed to the rather unsatisfactory results obtained in this location. Aside from the fact that the seed plots located in New Canada have not produced seed free from virus diseases, they have contributed considerable information on the spread of virus. From that standpoint these seed plots have been much more valuable than those at Masardis, for example.

1933. In establishing a seed plot in 1933, seed from three sources was used. One lot traced back to Baie Chaleur and one to Prince Edward Island, and the third was the increase from a hundred tuber-indexed hills planted the previous year on an exceptionally well-isolated farm in St. John Plantation. All 3 lots were found to include diseased tubers.

Planting was done on June 1, by which time much of the commercial acreage in the immediate vicinity had been planted. Roguing was delayed because of the late planting and was not completed until early August. Due probably to the open nature of the surrounding country, the distance of the seed plot from the overwintering hosts of the aphids infesting potato, and the date of planting, it was not until August 11 that aphids were observed in this plot (Table 11). At that time the aphid index was computed to be 2.8, and 1.39 per cent of the leaves were found to be infested. However, half of the pink and green potato aphids and all of the green peach aphids observed were winged. Since only a relatively small percentage of the members of an aphid colony are apt to be winged when vegetation is in a succulent condition, it seems logical to assume that these winged forms were dispersal forms coming from colonies established some time before on potatoes, or other secondary host plants, at a distance from the seed plot. Earlier planted potatoes were found 250 feet from the seed plot. The seed planted in this commercial field was badly diseased. From 30 to 40 per cent of the plants showed characteristic symptoms of several types of mosaic. Leaf roll plants also were found in all parts of this field. Because of earlier planting and the presence of so many diseased plants, the plants in the commercial field died much earlier than those in the seed plot. The plants in the seed plot were, in fact, killed by frost. Under these conditions, aphids infesting the plants in the commercial fields in this area would tend to produce dispersal forms as the potato plants died and a few of them, at least,

would almost inevitably find their way to the green plants in the seed plot.

1934. In 1934 the seed plot was planted the middle of May. Seed was taken from the 1933 plot and was selected for size so that units consisting of 4 normal hills could be planted.

Roguing was possible at an earlier date than in 1933. The first roguing indicated that there had been considerable spread of virus in 1933 (Table 9). Since the only type of mosaic found in the 1933 plot was mild, the finding, in 1934, of mosaics of both the crinkle and the rugose types is evidence of field-to-field spread of these viruses. The number of mild mosaic plants found would indicate also some field-to-field spread of this virus especially inasmuch as the original sources of infection present in the plot in 1933 had been largely removed before aphids were noted.

Many winged aphids (dispersal forms) were present in the 1933 seed plot during the latter half of August and the month of September. Since the available information indicates that these forms did not mature on potatoes planted in the seed plot, it appears that the winged forms must have come from other plants in the vicinity. Since almost three-quarters of the mosaic units removed in the first 2 roguings were split units,[19] late season spread of the virus producing symptoms of mosaic is indicated. The probable time of spread coincides with the aphid infestation and these 2 facts support the belief that the plants showing symptoms of virus diseases in the 1934 seed plot were growing from tubers produced by plants inoculated by aphids coming from commercial fields late in 1933.

Plants showing the symptoms of crinkle and of rugose mosaic were removed at the first roguing in 1934. Mild mosaic plants were found from time to time throughout the season and included 1 hill of current season infection (top part diseased from spread early in same season) removed on August 21.

Winged pink and green potato aphids were present in the 1934 plot early in July. At no time during the summer were aphids numerous. As in 1933 winged forms were found to be more numerous toward the end of the season than earlier but they were less abundant than in 1933.

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[19] Units in which only 1, 2, or 3 hills out of 4 from any 1 tuber show symptoms of disease are spoken of as split units.

The 1934 plot was located about 250 feet from a commercial field that had been planted with seed from the 1933 seed plot. This field was not rogued. Between 5 and 6 per cent of the plants in the field showed symptoms of mild or of crinkle mosaic. Some leaf roll plants also were present.

Because of earlier planting of the seed plot in 1934, the plants matured at about the same time as did those in surrounding commercial fields. There were fewer aphids in 1934 than were present the previous year (Fig. 2). Diseased plants in immediately adjacent commercial fields were decidedly less numerous than in 1933.

The combination of factors present in 1934 resulted in the elimination of the virus causing rugose mosaic but not of the viruses producing other types of mosaic (Table 8). The reduction in the number of plants having mild or crinkle mosaic was considerable. What disease was found in 1935 presumably resulted from the spread of virus within the plot in 1934 before roguing had been finished. There is no clear evidence of field-to-field spread of virus in this instance.

1935. In 1935 the seed plot was planted on June second, once more considerably later than much of the commercial planting in this area. Because there had been so much disease present in 1934 and nothing was known of the possible spread of virus during the season, two lots of seed from seed plots grown elsewhere in 1934 were introduced at New Canada in 1935. These 2 lots included more than half of the total number of hills in the plot. One lot was free from disease, the other contained a few plants showing the symptoms of leaf roll or of mild mosaic. Less than half of 1 per cent of the plants showed a faint mottle characteristic of a disease of uncertain etiology known locally as "weather mottle."

Although planted late, it was possible to rogue the 1935 seed plot early in July. Growing conditions in June and early July were favorable for the rapid growth of the plants and for the expression of disease symptoms. Plants showing the symptoms of mild or of crinkle mosaic as well as of leaf roll were detected and removed well in advance of the finding of aphids in the plot (Fig. 2).

As in previous seasons, the aphid infestation was slow in developing. A winged green peach aphid was found on July 25, while pink and green potato aphids and buckthorn aphids were not

seen until August 7. Winged forms were not prevalent at any time while the foliage was in such a state that counts were possible.

Surrounding commercial fields had been planted with seed from the previous year's seed plot and, while not free from diseased plants, did not contain a large percentage. Fields at a considerably greater distance from the seed plot contained nearly 90 per cent diseased plants.

Whether the mild mosaic found in the seed stock planted in 1936 resulted from the spread of virus within the plot during 1935 or was brought in by some of the dispersal forms that came to the seed plot late in July and early August of course cannot be determined. It seems significant, however, that roguing in 1935 was successful in eliminating the virus producing crinkle mosaic and that producing leaf roll (Table 8).

1936. Although the season of 1936 was normal, planting of the seed plot was delayed by various events until June 5, the latest date of planting of any of the seed plots grown at New Canada. The plants were slow in coming up and roguing was not possible until July 18, also the latest date for the first roguing at New Canada.

While mild mosaic plants were present in 1936 (Table 8) in a slightly higher percentage than in 1935, crinkle mosaic and leaf roll both had been eliminated from the seed stock as a result of the roguing done in 1935. The aphid index in 1935 was somewhat higher (14.6) at its peak than it had been previously, but fewer winged forms were found toward the end of the season. There is no conclusive evidence to indicate field-to-field spread of virus in 1935. Without this complication, the opportunity to remove diseased plants early in July 1935 proved to be sufficient to prevent the spread, within the plot, of the viruses producing crinkle mosaic and leaf roll. The small amount of mild mosaic present in 1936 resulted from the infection of relatively few hills in 1935.

While most of the plants showing symptoms of mild mosaic at any time during the season were removed on July 18 (Table 9), a few remained undetected until July 30. Sources of infection were thus present in the 1936 seed plot almost 3 weeks longer than had been the case in 1935.

The aphid infestation in 1936, while delayed as usual, developed during August to a point not previously recorded for this location. Winged forms became numerous and the infestation

continued into September. On August 26 the combined aphid index stood at 354, and 69 per cent of the leaves examined were found to be infested. Pink and green potato aphids accounted for most of the infestation.

The 1936 seed plot was located about 300 yards from commercial fields. These fields had been planted somewhat earlier than the seed plot. Less than 5 per cent of the plants in the nearest commercial fields were diseased. Fields somewhat farther away were found to be planted with seed that produced plants of which more than 80 per cent showed symptoms of mosaics of at least 3 kinds. The plants in these commercial fields died somewhat earlier than those in the seed plot.

1937. In 1937 seed from the 1936 plot was planted, again in June, after the commercial planting in the area was largely finished. The development of the plants was delayed by adverse weather conditions. Consequently, roguing was delayed until July 15 (Table 9). By that time, conditions were favorable for the expression of disease symptoms and all the diseased plants found, with the exception of those few showing symptoms due to current season infection, were removed by the end of the second roguing (Table 9). The data in Table 8 indicate that again, as in 1933, isolation of the seed plot from commercial fields was inadequate and field-to-field spread of the causal agents of leaf roll, crinkle mosaic, and rugose mosaic occurred.

Aphids were found in the 1937 seed plot early in July. Conditions remained favorable for their development throughout the season. Green peach aphids were found first on July 15. This species continued to increase until, in September, its index reached 1,035. The previous high for this species was 74.9 in August 1935.

Buckthorn aphids were present from early July until late August but their numbers remained small, the highest point reached being an index figure of 37.1 as compared with 3.9 in 1935, the previous high.

Pink and green potato aphids were numerous during August and September but did not reach the point established in 1936.

Aphids were present in the seed plot before any roguing could be done. They developed throughout the season and were present for a longer period than usual in September. The plot was again isolated from commercial fields by less than 300 yards.

1938. The number of diseased plants present in 1938 (Table 8) indicates that there was again considerable spread of the viruses producing mild and rugose mosaic and leaf roll. Crinkle mosaic was less prevalent than in 1937. There is no proof of field-to-field spread of virus here, since all diseases found in 1938 had been present in the seed plot in 1937. However, seed harvested on August 20 or before, when grown in 1938, was found to contain but few diseased tubers, and those produced plants showing symptoms of mild mosaic only. Among the tubers harvested at the usual time were some that produced plants showing the symptoms of crinkle or rugose as well as of mild mosaic.

CONCLUSIONS ON THE EXPERIMENTAL RESULTS OBTAINED AT NEW CANADA

The record indicates that this was an unsuccessful center.

Favorable factors included seed reasonably free from disease in the first instance and a location sufficiently far from the overwintering hosts of aphids to prevent early infestation of the seed plot by aphids, thus providing, in most instances, an opportunity to rogue before spread of virus occurred within the plot.

Unfavorable factors included total lack of isolation from unrogued fields, containing diseased plants, and late planting. These factors were sufficient to prevent successful handling of the seed plots planted at New Canada.

SPAULDING

1931. A seed plot was established in Spaulding in 1931. Seed for the plot was obtained from the same source as that from which the seed for the plot at Benedicta came. The plot was planted on June 12. This was at least a month later than the time of planting of commercial fields in this locality. Potatoes were breaking the ground in many places at the time the seed plot was planted. Roguing was impossible until the middle of July. A small number of diseased plants were found at first. Somewhat later, single stalks began to show symptoms of mosaic. When more than 5 per cent of the plants had been removed, largely because of what was probably current season infection, this plot was

dropped. No information is available concerning the aphid infestation in 1931 beyond the fact that pink and green potato aphids, green peach aphids, and buckthorn aphids were present and that there was a disproportionately large percentage of winged pink and green potato aphids early in July.

1932. A new start was made in 1932. Seed imported from Baie Chaleur was used for a part of the plot. The rest of the planting was made with Prince Edward Island seed that had been grown 1 year at Fort Kent. In Table 16, 2 sets of figures are given for the years 1932, 1933, and 1934. In each case the upper figures refer to the seed stock tracing back to Baie Chaleur, while the lower figures refer to that from Prince Edward Island. In 1935 and later the seed planted traced back to that originally secured from Baie Chaleur.

A plot was planted in Spaulding on June 1, 1932. There was considerable disease present (Table 16), especially in the stock 1 year removed from Prince Edward Island. The leaf roll content of both stocks was low. Conditions were not entirely favorable for the expression of the symptoms of mosaic, and it was not until the sixth of August that the last diseased hills to be detected were removed.

Detailed aphid counts were not made on this plot in 1932. The only information available is that there were many winged forms of both the pink and green potato aphid and of the buckthorn aphid in the plot during the latter part of August.

The plot was isolated from commercial fields by less than 200 feet. The seed planted in the commercial fields was sufficiently free from diseased hills to pass the state certification requirements.

In the fall before harvesting the seed plot, seed was saved from each of the 2 lots for planting in 1933.

1933. Planting in 1933 was done on June 2, somewhat later than the commercial plantings on this farm. The seed plot was located about 300 feet from commercial fields sufficiently free from diseased hills to qualify for state certification.

Most of the plants showing symptoms of mild mosaic were removed from the seed plot by the middle of July but a few diseased plants were found as late as August 8.

No plants showing the symptoms of crinkle mosaic were found in 1933, indicating that conditions in 1932 were favorable for the

elimination of this virus. Mild mosaic plants were found in 1933 to about the same extent as in 1932 (Table 16).

The aphid infestation in 1933 developed slowly but reached rather large proportions toward the end of the season when the index for the pink and green potato aphid reached 1,772 (Table 21) with 97 per cent of the leaves counted being infested. Buckthorn aphids were found before individuals of other species and continued to increase until the end of August when the index stood at 64. Green peach aphids were present during August but did not become numerous. Aphids were present before all diseased plants had been removed (Fig. 3).

1934. In 1934 the seed plot was planted on May 11. Isolation was again a matter of only a few hundred yards from commercial fields that passed certification after being rogued.

Early planting and favorable growing conditions made it possible to remove all plants showing the symptoms of leaf roll or of mosaic by the middle of July. Plants showing the symptoms of mild mosaic were present in about the same percentage as recorded the year before (Table 16). Plants showing the symptoms of leaf roll were slightly more numerous than they were in 1933. Spindle tuber was found for the first time, indicating that field-to-field spread of the causal agent of this disease must have occurred in 1933.

Buckthorn aphids were found in the seed plot on July 4 and were thus present long before roguing was finished. The infestation continued to develop throughout the season. At the peak of the infestation, the aphid index for the species reached 1,631 (Table 21). Neither the green peach aphid nor the pink and green potato aphid reached an index figure of 50.

1935. In 1935 the seed plot was planted on May 30. Conditions in 1934 were found to have been rather favorable for a reduction in the incidence of virus diseases. While there had been some spread of the virus producing mild mosaic (Table 16), that producing leaf roll was eliminated from this seed stock (Table 16).

Aphids were not as abundant in 1935 as they had been in 1934. The relative proportion of each species was similar, with the buckthorn aphid again most numerous.

The 1935 seed plot was isolated from commercial fields by about 500 yards, and the seed used to plant the commercial fields was nearly free from tubers producing diseased plants.

1936. Very little spread of virus occurred during 1935. The seed stock saved for planting in 1936 was found to be entirely free from plants showing the symptoms of mild mosaic or of leaf roll. Two hills with symptoms of mild mosaic were removed on August 21, but this was current season infection because the symptoms appeared only in the tops of the stalks affected.

The aphid infestation in 1936 was delayed, and it was not until the third week in July that pink and green potato aphids were found in the seed plot which was planted on June 6. It was the latter part of August before the other 2 species were recorded from the plot. Under the circumstances, it seems evident that the infestation was established by dispersal forms rather than migrants. The planting of the seed plot occurred much later than commercial plantings on this same farm. These commercial plantings, if only because of their size, were most likely to be the source of dispersal forms. The pink and green potato aphid was the dominant species in point of numbers during this season, and nearly 10 per cent of the individuals of this species were found to be winged the latter part of August.

1937. Since current season symptoms of mild mosaic had been found in August 1936, it was not surprising to find, in 1937, that mild mosaic plants were again present in this seed stock. The leaf roll virus also was found to have re-entered.

The plot was planted on the second of June and was not especially well isolated from other plantings on the farm. Roguing was possible early in July and the last diseased plants found were removed on July 22.

The aphid infestation started early—buckthorn aphids being found the latter part of June. The infestation increased until the middle of August, after which it began to decline. The pink and green potato aphid reached its peak (index 31) slightly later than the buckthorn aphid. The green peach aphid was the dominant species, in point of numbers, for the first time since observations have been made in Spaulding. It reached an index peak of 132 and then began to decline. At the peak of its infestation, 43 per cent of the leaves examined were infested (Table 22).

1938. In the fall of 1937 a representative sample of tubers was taken from 50 barrels of seed from the seed plot. This was planted on Aroostook Farm in 1938 as a means of ascertaining what had happened in 1937. The reading made of the plants grow-

ing from the tubers of the sample indicated that both mild mosaic and leaf roll had increased in this stock. Five and four-tenths per cent of the plants showed symptoms of mild mosaic, while an additional 1 per cent of them showed symptoms of leaf roll.

CONCLUSIONS ON THE EXPERIMENTAL RESULTS OBTAINED AT SPAULDING

The record indicates that this center was satisfactory in certain seasons and unsatisfactory in other seasons. In 1934, 1935, and 1936, the seed stock grown was sufficiently free from disease to certify easily. In the other seasons it would have required roguing to obtain a creditable reading on the inspection slip.

Unfavorable factors included inadequate isolation, late planting, early appearance of aphids, and seed that, at the start of the experiment, contained too many diseased hills.

Favorable factors included the ability to remove most of the diseased plants by the middle of July in most seasons, and the rather slow development of the aphid population in July in some seasons.

Lack of isolation of the seed plot from commercial fields appears to have prevented this center from being entirely successful.

WOODLAND

1934. In 1934 a seed plot was established in the town of Woodland. Seed for this plot was taken from a field on this same farm, planted in 1933 with potatoes grown in 1932 on the farm in Masardis on which experimental seed plots have been located since 1931. A reading made in July 1933 on 3,000 hills at random before roguing disclosed but 2 hills showing symptoms of mosaic and 1 showing leaf roll.

That there was considerable spread of virus in 1933 is indicated from the record (Table 24) of the roguing done in the 1934 tuber-unit seed plot. It may be seen from Table 25 that only about 20 per cent of the mosaic plants detected during the season were removed in the early roguings. It is believed that these hills present the true picture of the spread in 1933 of the virus producing mild mosaic and that they served as the sources of inoculum for

the current season infection of "healthy" hills in 1934 that resulted in a much larger number of diseased plants being removed during the latter part of July and the early part of August. All of the hills removed after the middle of July showed the symptoms of mosaic in the tops only; a fairly reliable indication of current season infection, especially when such hills are not found to be grouped in tuber units.

The aphid infestation in 1934 presented many interesting phases. The infestation was almost entirely limited to buckthorn aphids. Only 2 green peach aphids were found throughout the season. A few more pink and green potato aphids were found, but the index for this species did not rise above 2. Buckthorn aphids must have been present by the middle of June because when the first aphid count was made on July 4, colonies were found in which wingless, viviparous females were present. These females had matured on potato and had, in turn, given birth to young that were nearly mature on July 4. Many winged forms were present and several were seen in flight, indicating that these aphids were actively establishing new colonies. The index on July 4 stood at 99.7 with 22 per cent of the leaves examined being infested (Table 26). The infestation started in one corner of the plot and advanced steadily until the whole plot was infested. It was interesting to find that the plants showing current season symptoms of mosaic were largely grouped beyond the places where units showing the symptoms of mild mosaic had been removed and in the direction in which the infestation developed.

By the time that winged migrants were no longer found, winged dispersal forms were beginning to appear. Winged forms were thus present throughout the season.

The infestation increased rapidly during July and August. An index figure of 1,625 was recorded on July 24 (Table 27). On August 6 the infestation was so heavy that a count was impossible and a record was made only of the number of leaves infested. Ninety-three per cent of all leaves examined were found to have buckthorn aphids feeding upon them (Table 27). Three leaves were actually counted out of curiosity and the average infestation of these was found to be over 1,500 per leaf. An index figure of over 100,000 is thus indicated, this being the largest figure recorded from any of the experimental plots at any time since observations have been made. In many instances when lower leaves

were lifted, the soil underneath was found to be white with cast skins, and the outline of the leaf was clearly demarcated. The infestation began to decline toward the end of August and the return migration took place, as usual, early in September.

As would be expected from the current season spread of the virus causing mild mosaic that became evident in August, the potatoes harvested in the fall were not especially desirable as seed. Spread of the virus apparently took place throughout the season (Table 28).

1935. A commercial field, planted with seed taken from the seed plot at the end of the season in 1934, was found the following year to contain plants, more than 8 per cent of which showed symptoms of mild mosaic.

The 1935 seed plot was planted with seed from several sources, including seed early harvested from the previous seed plot. This early harvested seed was found to be free from leaf roll but contained mosaic plants to the extent of nearly 1 per cent. The leaf roll virus does not appear to have spread under the conditions found here in 1934.

Growing conditions were quite favorable for the expression of disease symptoms in 1935. Roguing was possible at an early date.

Aphid infestation of the seed plot occurred somewhat later in 1935 than it did the year before. The green peach aphid was not found in the plot during the summer. The buckthorn aphid was once more the dominant species in point of numbers (Fig. 4), the index figure at the peak of the infestation reaching 124. The plants were killed by late blight toward the end of August, a fact that doubtless influenced the course of the aphid infestation.

1936. Counts made in 1936 in a field planted with seed from the 1935 seed plot indicated that there had been some spread of the virus causing mosaic and of that causing leaf roll during the 1935 growing season (Table 24).

CONCLUSIONS ON THE EXPERIMENTAL RESULTS OBTAINED AT WOODLAND

The record indicates that this was an unsuccessful center.

Favorable factors included early planting and an opportunity to remove diseased plants, growing from tubers infected during a previous season, at a reasonably early date. The amount of dis-

ease present at the start of the experiment was not excessive.

Unfavorable factors included proximity to buckthorn, lack of isolation as evidenced by the re-entry of the virus producing leaf roll after it once had been eliminated, and, probably, late season spread of the virus producing mosaic from a small number of hills infected before roguing could be finished or from hills infected by aphids coming from fields at a distance from the plot.

Smyrna Mills

1933. A seed plot was established near Smyrna Mills in 1933. The farm selected was located in an area where considerable table stock was grown. The soil type was satisfactory and the cropping practices were such that the land was in a good state of fertility. The seed planted in 1933 was taken from a tuber-unit seed plot raised on this farm in 1932. It had come that spring from the farm in Benedicta where an experimental seed plot had been established in 1931. There is no exact record of the number of diseased plants removed in 1932, but there is good reason to believe that the grower is correct in his recollection that they were fewer than half of 1 per cent of the total number of hills in the plot.

Plants showing symptoms of leaf roll and of mosaic were found in the 1933 plot (Table 29). The plot was planted early in June which accounts for the fact that roguing was delayed until July 10. Diseased plants continued to be found in the plot until the middle of August (Table 30). Many of those found after the middle of July were parts of units, the other hills of which appeared to be healthy. Since most of these diseased plants showed symptoms throughout, it is assumed that they came from partially infected tubers produced by plants that were inoculated late in 1932.

The aphid infestation in 1933 was moderate. It was initiated by dispersal forms. On August 2, 1 per cent of the leaves were infested. Forty-five per cent of the leaves counted were infested by the middle of the month. At this time pink and green potato aphids were more than 4 times as numerous as green peach aphids. Only 1 buckthorn aphid was encountered on the leaves examined. A number of winged aphids were present. Eleven per cent of the green peach aphids counted were winged. This is a somewhat higher percentage of winged forms than would be expected in an

aphid population with an index of 33.6 and suggests the presence of dispersal forms that developed on other secondary hosts (chiefly potatoes in neighboring fields) in the vicinity.

The seed plot was planted about 25 feet from an unrogued commercial field on the adjoining farm. Some 20 per cent of the plants in this field were diseased.

1934. In 1934 a part of the seed plot was planted with seed harvested at the usual time. The figures in Tables 29 and 30 refer to this portion of the plot.

It is evident (Table 29) that little success was achieved by roguing in 1933. On a percentage basis, there were more plants showing symptoms of leaf roll and of mosaic than had been removed the previous summer. As had been the case in 1933, the plants removed in the latter part of July and during August were from split units, indicating that spread of the causal agent took place rather late in the season. Since aphids were present before all diseased plants had been removed, it is impossible to determine how much, if any, spread was from fields at a distance from the seed plot.

It seems likely (Table 33) that spread occurred more or less continuously throughout the season. Split tubers may have occurred either as a result of late season, field-to-field spread of the virus producing mild mosaic or as a result of secondary spread within the seed plot. Early harvesting of seed reduced the amount of disease as compared with late harvested seed but not to the point achieved in certain other plots.

Aphids were found earlier in 1934 than they were in the previous year. Buckthorn aphids were present from July 12 on and were more numerous than other species throughout the season (Fig. 5).

1935. No experimental seed plot was planted here in 1935. A reading was made in a commercial field planted with seed from that part of the 1934 seed plot for which figures are given in Table 29. This count indicated that roguing in 1934 was no more successful than it had been the previous year. The percentage of plants showing the symptoms of leaf roll was reduced considerably; that of plants showing symptoms of mosaic increased so that about 8 per cent of those growing in 1935 showed symptoms of this disease.

In retrospect and in the light of present knowledge, it is easy to determine some of the reasons for the failure to reduce mosaic to a lower figure. In the first place, isolation was inadequate. Table stock was being grown on all of the surrounding farms. Many of the seed stocks being used for this purpose were diseased—in some, the mosaic content was as high as 20 per cent of the plants, a satisfactory situation as far as yields of table stock are concerned. The seed plots were planted later, not earlier than, many of the neighboring commercial fields. This often resulted in the maturing of these commercial fields at a time when the seed plots were still green. During both seasons there were sufficient aphids to bring about spread of virus within the plot before diseased plants could be removed, as well as from adjacent unrogued fields.

Conclusions on the Experimental Results Obtained at Smyrna Mills

The record indicates that this was an unsuccessful center.

There appear to have been no favorable factors in the conduct of this experimental plot.

Unfavorable factors included lack of isolation, late planting, too many diseased plants, delayed roguing, and initiation of aphid infestation by dispersal forms.

Benedicta

South of the village of Benedicta on the old stagecoach road, in what is now an unnamed township in Aroostook County, is a clearing in the forest. Over one hundred miles south of Presque Isle, it is at the southern limit of cultivated land in Aroostook County. Here, in other days, was a stagecoach stop and a tavern. Land was gradually cleared about the buildings, but when the new road into Aroostook County took another course, this farm was no longer operated. At the time of the World War, it was again cultivated. In 1930 another crop was planted here. Some 5 miles below the village of Benedicta, the farm is isolated from other potatoes in a way not duplicated by any of the other experimental areas studied. Transportation difficulties convinced the operator

who farmed the land in 1930 that it was not worth the effort, and the lease passed into other hands.

The soil type is not that considered to be the best potato land. A part of the farm consists of heavy soils which, when planted, are likely to produce tubers rather seriously injured by wireworms. Other fields do not harbor wireworms and produce a satisfactory crop if sufficient moisture is available at critical periods. From time to time the potato plants have suffered from lack of moisture. Premature dying from this cause has been experienced. Much difficulty has been experienced with weeds, especially witch grass. The land is relatively high and too well drained. The farm is surrounded by forest. There are no swampy areas near the farm and buckthorn has never been found close at hand. Escaped rose bushes are abundant near the old buildings and, on these, pink and green potato aphids develop each spring and winged individuals fly from the roses to potatoes and other secondary hosts. Although no foxgloves are known to be growing anywhere in the vicinity, the foxglove aphid has been found during 2 seasons. The green peach aphid has likewise been common, although its known overwintering host has not been located within a considerable distance of the farm. It is possible that the constant travel between other potato areas and this farm may be responsible for the unwitting introduction of certain of the aphid species found here.

Seed for the 1931 seed plot was imported from Plaster Rock, New Brunswick.

1931. On May 15, 1931, a seed plot was planted by hand in tuber units at Benedicta. It was rogued 5 times during the summer (Table 35). Both leaf roll and mosaic plants were removed (Table 34). These figures indicate the original condition of the seed stock at the beginning of the experiment.

The plot was first visited on July 3, 1931. Pink and green potato aphids were present at that time and must have been there for at least 10 days, as young aphids were found in colonies which included wingless, viviparous females. The assumption is that these females developed on potato and were the progeny of winged migrants from escaped roses growing on the farm.

It was not until July 15 that a small number of green peach aphids were found. The pink and green potato aphids had increased considerably in numbers by this time.

No diseased plants were recognized after July 30, 1931 (Table 35). No data are available on the aphid population during August. At the end of July, the pink and green potato aphid was abundant, especially on the blossoms, and practically every plant in the seed plot was infested. Green peach aphids were much less numerous and were found chiefly on the lower leaves. The infestation was much more restricted and involved a smaller percentage of plants than in the case of the pink and green potato aphid.

Aphids were relatively abundant in this seed plot before any roguing was done. As far as observations went, the pink and green potato aphid was the only species present at the time roguing commenced. Hills were selected adjacent to diseased units removed in 1931 and planted in 1932 to determine, in so far as possible, what effect those aphids present during July had on possible spread of the virus producing mosaic. It is evident (Table 39) that not much spread of the mosaic virus resulted. While not all spread of virus occurring in a seed plot is to hills adjacent to diseased hills, much of any spread is likely to be (*17*, p. 58).

If much spread of the mosaic virus had taken place, diseased plants would have appeared in 1932 in the general planting from the seed produced in 1931. All the seed produced was planted in 1932 in commercial fields. A count of 6,000 hills, in groups of 100 at random in the commercial fields before any roguing was done, indicated that there were, on the average, but 2 mosaic plants per 1,000 observed. Such a figure is evidence of but little spread of virus in 1931.

Due to the necessity of driving 100 miles to reach this plot and to the fact that roguing was considered to be of more importance, no detailed aphid counts are available. Consequently no aphid index can be calculated in this instance.

1932. In 1932 a seed plot was again planted by tuber units. The seed used was taken from the 1931 seed plot and had been selected by the grower only for size and shape. The season of 1932 was somewhat later than 1931 and no roguing was possible until July 5. Weather conditions were favorable for the expression of disease symptoms, and most of the diseased plants found were removed by July 12 (Table 35).

An attempt was made in 1932 to eliminate a faint mosaic disease known in Aroostook as "weather mottle." Observations indicate that this disease is associated with certain seed stocks

tracing back to certain areas in New Brunswick. It is not considered a serious disease from an economic standpoint but is certainly undesirable in seed stocks. Table 34 indicates the effectiveness of the roguing done in 1931. It will be seen that, although some reduction in the percentage of leaf roll plants was recorded, the percentage of mosaic plants remained the same.

The pink and green potato aphid was first observed on this farm on May 16, 1932, on a rose bush. A week later members of the second generation on rose were found. About 1 rose cane in 50 was found to be infested on May 24. The first winged female was not found on potato until July 5. The infestation on potato increased steadily. By the 26th of July, aphids were quite abundant. Green peach aphids were present in small numbers. By the 3rd of August, 76 per cent of the leaves examined were infested. Of the top leaves, 95 per cent of those examined were infested by the pink and green potato aphid (Table 36). Another aphid count was made on August 15. During the interval between counts, the weather was sufficiently damp to permit the rapid development of a fungus that feeds on insects. The reduction in the number of aphids was most marked on the upper leaves. On the 15th only 33 per cent of the upper leaves examined were found to be infested (Table 37). Some parasitism was noted, but most of the reduction in infestation must be attributed to the fungus. What remained of the infestation was confined largely to middle and lower leaves. Fifty-one per cent of all leaves examined were found to be infested. Green peach aphids were present on 11 per cent of the middle and 33 per cent of the lower leaves examined on August 15. A few specimens of the buckthorn aphid were found for the first time in a very small area in the plot where roguing had commenced. This species was abundant in other parts of the county and many have been accidentally introduced into this plot. It was not found in any other fields on this farm.

The pink and green potato aphid was being attacked almost exclusively by the fungus on August 15.

During the next few weeks, the infestation increased slightly but never reached the peak it attained before the fungus checked it early in August.

Winged pink and green potato aphids were found on August 3 and were relatively more numerous as the season progressed. There was considerable dispersal during the latter part of August.

As a result of the information gained (Table 39) by harvesting hills adjacent to diseased hills removed, a careful survey was made of the seed plot before digging in the fall of 1932. Wherever a diseased unit had been removed, a stake had been placed indicating the date of the removal of mosaic or of leaf roll plants. The location of these stakes and their small number made it possible to select several areas within the seed plot from which no diseased units had been removed. The tubers harvested from these areas were stored by themselves and utilized for the planting of the 1933 seed plot.

This method of selecting seed did not prove to be entirely successful (Table 34). No "weather mottle" was detected in 1933, but weather conditions were not favorable for its recognition. On a percentage basis both leaf roll and mosaic were, however, reduced.

1933. Spread of the mosaic virus did not occur extensively in 1932. The amount of mosaic found in commercial plantings grown from unselected seed from the 1932 seed plot was slightly less than twice that found in the 1933 seed plot. There was thus a slight advantage in selecting seed from areas in the seed plot from which no disease was taken. Some hill-to-hill spread of the virus producing mosaic was avoided. The tubers found to be harboring mosaic, being 4 in number, came, in all likelihood, from one hill infected during 1932—doubtless at some distance from a diseased unit—perhaps by a winged aphid coming to the seed plot from another field on the farm.

On July 23, a count of the aphids in the seed plot, based on an examination of 246 leaves, showed that 12 per cent of the leaves examined were infested. This count revealed the presence of the green peach aphid in greater abundance than the pink and green potato aphid (Table 37). The former species was confined entirely to the lower leaves, 22 per cent of those examined being infested on this date. Another count made on August 2, after the last of the diseased hills had been removed, revealed that 32 per cent of the leaves examined were infested. Pink and green potato aphids were then most abundant but green peach aphids were almost as numerous and were no longer confined to the lower leaves. On August 2, 1 colony of the buckthorn aphid was found, again near the place where roguing had commenced. It is felt that this species was introduced accidentally from another plot some 14 miles away

where this aphid was especially abundant. This point is further supported by the fact that, although careful search was made of the plot from time to time throughout the rest of the season, this species was not found in any other location in the plot nor in other plantings on this farm.

During the rest of August, counts were made on a less extensive scale. These counts disclosed a gradual increase in the population until 73 per cent of the leaves examined were infested (Table 38). Weather conditions became favorable for the development of the fungus that attacks the aphids, and a reduction in the infestation was noted before the foliage died.

1934. In the spring of 1934 the rose bushes adjoining the potatoes were burned over. No aphids were observed in these areas but the species was found on roses growing elsewhere. The initial infestation on the potatoes was reduced to small proportions. Individuals of the pink and green potato aphid, presumably from wild roses in the vicinity, were found in the seed plot on July 2. By July 22, when a count was made of 486 leaves, 23 individuals of this species were observed. Other species brought the total number of aphids observed on this date to 220 (Table 37).

In another count on August 4, only 73 individuals of the pink and green potato aphid were found on 111 leaves. Buckthorn aphids were most numerous at this time (Table 38). This year the buckthorn aphid was found on this farm early in the season, and it was established in all parts of the various plantings on this farm.

Elimination of mosaic in 1933 proved possible in this location. Reduction of leaf roll also, but not elimination, was possible here.

Not until 1934 was the buckthorn aphid found in large numbers or early in the season. It has not played here the role it has played elsewhere in the dissemination of mosaic virus before roguing could be completed.

It has been possible to select seed for the next year's seed plot from areas from which no diseased plants had been removed. The number of diseased plants appearing in the next year's seed plot has been limited to those few growing from tubers produced by plants that became infected at some distance from units removed during the current season. Hill-to-hill dissemination of mosaic virus has been largely avoided. With a similar favorable combina-

tion of factors, progress in the elimination of virus from potato stocks should be possible in other locations.

The seed stocks harvested in the fall of 1934 were taken over in 1935 by the Eastern States Farmers' Exchange for their foundation Green Mountain seed.

CONCLUSIONS ON THE EXPERIMENTAL RESULTS OBTAINED AT BENEDICTA

The record indicates that this was a successful center.

Favorable factors included seed containing less than one-half of 1 per cent diseased tubers, isolation sufficient to prevent farm-to-farm spread of virus, early planting, early roguing, adequate expression of the symptoms of disease, growing conditions that resulted in early maturity, somewhat delayed aphid infestation, especially of the buckthorn aphid, and an opportunity to select seed from areas in the seed plots from which no diseased units had been removed.

Unfavorable factors included inadequate isolation of the seed plot from the commercial fields on the farm and inability to remove all diseased plants from commercial fields in time to prevent all spread, to healthy hills, of the virus producing mosaic.

MASARDIS

Of all the areas where experimental seed plots have been located throughout the duration of this study, the one located in the town of Masardis has proved to be the one area best adapted to the purposes of the project. The results obtained here—from the standpoint of virus diseases particularly—have not been duplicated elsewhere. The farm is located about 3 miles west of state highway 11 and some 7 or 8 miles southwest of the village of Ashland. It is located to the west of other cultivated land in the town (township) of Masardis and so is surrounded by woods. These woods extend for many miles to the north, to the south, and to the west. Eastward the woodland extends from one-quarter to one-half mile before cleared land is encountered. No potatoes are normally grown within a distance of at least a mile from the eastern boundary of the farm.

In 1930 what is now cultivated land was covered with dense second-growth timber. The area had been lumbered years before. In 1931, at planting time (Table 40), 5 acres of land had been cleared and made ready for a crop. There were 3 fields, one of 3 acres and 2 of 1 acre each. The clearing of land has progressed steadily so that it was possible in 1938 to plant about 60 acres of potatoes. A three-year rotation has been followed, oats and clover being planted the year following potatoes, and the clover being plowed under at the end of the second season.

Most of the farm is well drained. The few wet areas are being filled with the stones taken each year from the cultivated fields. No brush and few weeds are allowed to grow about the stone piles. While some land is often too wet to permit planting in the spring, there are no permanently swampy areas on, or near, the farm. For this reason, one does not find plants characteristic of damp situations in the immediate vicinity of the farm. About ¾ mile westward is a slow flowing brook. Here are found such plants as wild rose (*Rosa nitida* Willd.)[20] which are undesirable from the standpoint of a seed potato grower. There are several large springs on the farm. These flow throughout the year, thus indicating that there is considerable underground water present. Rainfall has been adequate to insure a crop. While dry periods have occurred, they have not been, thus far, of such duration that the plants have suffered.

Much of the cleared land now in cultivation was originally hardwood ridges. The predominating soil type is not that considered to be the best for raising potatoes. It is, however, entirely satisfactory and has produced, on occasion, crops equivalent to 200 barrels per acre. The soil has been derived from sandstone which underlies much of the farm. Limestone underlies the best potato soils in Aroostook County.

1931. For some years the owners of this farm had been purchasing foundation seed in Canada each year, so it was natural that they should turn to this source for the foundation seed planted in 1931. The particular strain of Green Mountains selected had been planted by tuber units and carefully rogued for a number of years. The Canadian grower had been raising about 5 acres a

[20] Determined by F. H. Steinmetz, Professor of Botany and Entomology, College of Agriculture, University of Maine.

year and so had had ample opportunity to rogue each crop carefully and more frequently than could a larger grower. That he had done a remarkably thorough job is shown in Table 40.

While the stumps had been pulled and the brush cut when the spring of 1931 came, no plowing had been done. For this reason the spring work occupied more time than usual and planting had to be delayed until June 9. In spite of cross plowing, the soil was not in especially good condition in 1931. Fine roots, sods, etc., interfered with cultural practices. Plant growth was not uniform, and the potato vines were somewhat lighter in color than is normal. Detection of mosaic and leaf roll was thus difficult and there can be no definite assurance that the 1 unit showing symptoms of mosaic and the 5 units showing symptoms of leaf roll found were the only ones in the plot (Table 42). The amount of mosaic and leaf roll found in 1932 was small enough, however (Table 40), to be explained on the basis of transmission of virus to healthy hills (Table 48) rather than on the basis of incomplete roguing.

On July 1, 1931, pink and green potato aphids were found on *R. nitida* growing along a stream some three-fourths of a mile west of the seed plot. These were wingless, viviparous females, presumably daughters of the stem mothers which had hatched from overwintering eggs some time before. Although many rose bushes were present and a goodly number were examined, few aphids were found. No winged forms were observed. Due to late planting, the potatoes were barely through the soil at this time and no extensive examination of the plants was made. On those plants examined no aphids were found.

On July 8 the plants were large enough to permit of roguing and of examination for aphids. In this instance a count was made while passing diagonally across the field. Three leaves of one plant in each of 98 rows were examined. The usual practice of selecting 1 leaf at the top, 1 near the middle, and 1 at the bottom of each plant was followed. At this time no aphids were found. The seed plots were rogued a second time on July 13. On this date no aphids were found on the leaves examined, in this instance all leaves of 32 plants taken from various parts of the 3 seed plots. Counts were made on July 21 based on 3 leaves of each of two plants in each of 98 rows. Both diagonals were traversed in making these counts. Seven winged, viviparous pink and green potato

aphids and 2 winged, viviparous buckthorn aphids were discovered. In another plot on the same farm, a count based on 3 leaves of one plant in each of 42 rows revealed 20 specimens of the buckthorn aphid and 13 of the pink and green potato aphid. One of these 13 was an immature form, obviously the progeny of a wingless, viviparous female that had matured on the potato. Roughly, 2 weeks must pass between the deposition of the young aphid by a migrant form and its maturity. It is likely that spring migrants reached the potato fields at least 2 weeks before this colony was discovered. From what is known of the life history of this insect in Maine (*26*, p. 323), these spring migrants were probably the progeny of the second generation on rose. The earliest of the spring migrants, the progeny of the stem mothers, presumably were on the wing too early to colonize potatoes planted as late as these were in 1931.

By July 29 pink and green potato aphids were more abundant than buckthorn aphids. Many of the latter were winged. It is evident that the buckthorn aphid was dispersing at this time.

It was interesting to find that most of the infestation occurred near the center of one of the plots, very few aphids being found near the edges.

Plants showing the symptoms of mosaic were removed at several different times during the summer. By digging hills adjacent to these diseased plants, always allowing sufficient time for any virus transmitted to penetrate the tubers, it was possible to gain some idea concerning the date of dissemination of the virus producing mosaic in relation to the date of roguing and the development of the aphid infestation. In this instance tubers from 3 different plots on this farm were included. The results (Table 48) indicate that there was relatively little transmission to nearby hills of the virus producing mosaic. However, there was enough spread (Table 40) to result in a 20-fold increase of mosaic plants on a percentage basis. Actually, but 10 tubers were found to be diseased in 1932. Since the seed planted in 1932 was unselected except for size and shape and represented tubers harvested from a definite area of the 1931 plot, it is likely that the 10 diseased tubers came from not more than 2 hills. The assumption is that these 2 hills became infected during 1931.

1932. As in 1931, spring work in 1932 occupied much more time than is usually required. The land selected for the seed plot

had been cleared in 1931 and somewhat the same difficulties were again encountered. Planting was done June 7, only 2 days earlier than in 1931.

Previous experience with seed plots had convinced the owners of the farm that it was unwise to count on their own seed for their seed plot in 1932. For this reason new seed was imported from Canada for a part of the 1932 seed plot. Seed from the 1931 plot was used for 10 rows of the 1932 seed plot. The figures in Table 40 refer to these 10 rows only.

In 1932 the aphid population did not build up rapidly until early August. Conditions then became favorable for the aphids and considerable increase in the population was noted. In the case of the pink and green potato aphid, a larger population was encountered in 1932 than has ever been recorded from this farm. The percentage of leaves infested by this species at this time has not since been surpassed here (Table 45).

Certain of the commercial fields on this farm were planted earlier than the seed plot because the land was ready before that on which the seed plot was planted. In these fields, aphids appeared much earlier than they did in the seed plot, which was separated from the commercial fields by a strip of woodland about 100 feet wide. The seed plot was also farther away from known overwintering host plants from which aphids migrate in the spring. Again the infestation of the seed plot may have been established by late migrants. In this case it is also possible that dispersal forms were responsible.

By the end of July there were still relatively few aphids present in the seed plot. On August 6 a count indicated that 41 per cent of the leaves examined were infested. Most of the aphids were pink and green potato aphids. A few buckthorn aphids were present, as were some green peach aphids. This is the first record of the occurrence of the green peach aphid on this farm. On August 13 the infestation had increased until 73 per cent of the leaves examined were infested (Table 44). Most of the increase was accounted for by the pink and green potato aphid. Some increase was also noted in the numbers of the green peach aphid but there were fewer buckthorn aphids than were present at the previous count.

Winged pink and green potato aphids were relatively abundant. Winged forms of the other 2 species were not noted.

On August 26 another count indicated that 90 per cent of the leaves examined were infested (Table 45). Parasites were active in the plot and many individuals of the pink and green potato aphid had been destroyed by a fungus. The infestation did not increase beyond this point but declined rapidly under the influence of parasites, predators, a fungus, and the dying of the potato vines. With but one exception (1937), no larger percentage of leaves has been found infested by aphids here. All diseased plants detected in 1932 had been removed prior to the period of maximum aphid infestation.

From a consideration of the data (Table 48) obtained from the harvesting of hills adjacent to certain diseased units removed at different times during the season of 1932, it appears that, as in 1931, some spread of the virus producing mosaic took place long before the date of maximum aphid infestation.

In this vicinity the buckthorn aphid is known to have migrated by the last week in June. Winged individuals of the pink and green potato aphid were present on rose on June 23 so that migration must have started by that time. It seems evident (Table 48) that some transmission of the virus producing mosaic must have taken place while the aphid population was relatively small. It is true also that some diseased units remained undetected later than was the case in 1931 (Table 42).

1933. In 1933 a composite sample from the 1932 seed plot was planted. The tubers were selected for size and shape by the grower. The usual difficulty was experienced in planting, which was not possible until June 2. Roguing was done by the trained plant pathologist who had been hired to rogue the commercial fields. It will be seen from Table 40 that there was no increase in mosaic plants on a percentage basis but that the virus producing leaf roll had spread considerably. This stock was not continued in a seed plot beyond 1933.

An inspection of certain fields in New Brunswick in 1932, when very few mosaic and fewer leaf leaf roll plants were found, led to the importation, once again, of Canadian seed for the 1933 seed plot. This was done because the results in 1932 had been little more promising than those obtained earlier, and in this instance the object in view was disease-free stock—an object to be attained by the most promising method, which, in this case, was certainly the importation of new seed.

Conditions in the spring of 1933 were unfavorable for aphid development. Large numbers of parasites and predators had been observed toward the end of the summer in 1932. It seems evident from limited observations that more parasites and predators than usual overwintered. These probably reduced the number of spring colonies on the primary food plants. Migrating aphids were fewer in number and did not reach potatoes until considerably later than usual. Weather conditions also were unfavorable for aphids during the early part of the summer.

A careful examination of the seed plot on July 22 revealed but 2 small colonies of the buckthorn aphid. On July 31, 2 pink and green potato aphids were found in addition to some buckthorn aphids. By August 11, 10 per cent of the leaves examined were infested (Table 45). On this date the first individuals of the green peach aphid were encountered. Eleven days later it was found that the pink and green potato aphid had increased rapidly. An increase was noted in the numbers of the green peach aphid also. An appreciable reduction in the number of buckthorn aphids was revealed. The pink and green potato aphid was found to be infesting 74 per cent of the top leaves examined at this time. Of all leaves examined, 69 per cent were infested by 1 or more of the 3 aphid species. The infestation continued to increase until about September 1 when it dropped off rapidly.

The available data indicate that what increase in mosaic took place did so at a somewhat later date than in 1931 or 1932 (Table 48). The fact that this roughly corresponds to the development of the aphid infestation is at least interesting (Fig. 6).

On August 12, 1933, potato tops were pulled up from a number of hills in the seed plot. The tubers harvested from these hills some 2 weeks later furnished seed for part of the 1934 seed plot.

1934. By the spring of 1934 sufficient land had been cleared to permit of a 3-year rotation. This year the seed plot was located on soil previously planted and relatively free from the roots and sods that had caused so much annoyance in previous years. Because little spring work needed to be done, planting was possible on May 14. Several lots of seed were used. Six thousand seven hundred and twenty hills were planted with seed harvested from hills from which tops had been pulled on August 12, 1933. Five thousand one hundred hills were planted with tuber indexed *(1)*

seed which was a random sample from the 1933 commercial crop grown on this farm.

By the last of May the economic outlook had improved and it was decided that the seed plot would have to be enlarged to supply enough seed for the following year. On May 31, 3,360 hills were planted with seed taken from the 1933 seed plot on August 31, 1933, and 3,560 hills were planted with tuber indexed seed. The final plot contained 18,740 hills.

No mosaic plants were found in the seed plot during 1934 although the plot was rogued 6 times (Table 42). No leaf roll plants were found in the early harvested seed, but 34 hills showing symptoms of leaf roll were removed from the other lots.

Fewer aphids were recorded from the seed plot in 1934 than in any other year (Tables 43, 44, 45). At the peak of the infestation there was, on the average, but 1 aphid per 15 leaves examined. The green peach aphid was not observed in the seed plot in 1934. Two specimens of the foxglove aphid were recorded on July 3 when 176 leaves were examined. Six colonies of the buckthorn aphid (21 wingless and 2 winged) and 1 colony (2 wingless individuals) of the pink and green potato aphid were noted.

On July 12 a count of 184 leaves disclosed but 1 colony each of the buckthorn and of the pink and green potato aphids. In each case 7 wingless aphids were counted.

On July 23 a count of 168 leaves disclosed 5 colonies of the buckthorn aphid (10 wingless individuals) and 2 colonies (6 wingless individuals) of the pink and green potato aphid.

During August no detailed counts were made in this seed plot, but examinations made at the usual intervals indicated that there was no increase in the infestation during the month. Occasional winged forms were found, indicating that some dispersal from secondary hosts in the vicinity was probably taking place.

No data are available on the time of dissemination of the virus producing mosaic because no mosaic plants were removed from this plot in 1934.

Small lots of seed were early harvested from the 1934 seed plot on July 26 and August 14. Most of the seed for the 1935 seed plot was early harvested on August 24, 1934. All 3 lots were taken from some of the 6,720 hills grown from tubers early harvested from the 1933 seed plot.

1935. These 3 lots of seed were planted in a seed plot on May 16, 1935. Each lot was kept separate. The lots early harvested on July 26 and on August 14 were entirely free from plants showing symptoms of leaf roll or of mild mosaic. Two hills showing symptoms of "weather mottle" were removed. The lot early harvested on August 24 was found to include 20 hills (7 tubers) showing symptoms of mild mosaic, 4 hills (1 tuber) showing symptoms of leaf roll, and 28 hills (7 tubers) showing symptoms of "weather mottle." Conditions in 1934 were not such that "weather mottle" was evident. There is no way of knowing how much was present in the stock and unknowingly propagated by planting tubers produced by plants having "weather mottle" in 1934 and how much of that found in 1935 was due to current season infection of healthy hills.

The presence of mosaic and leaf roll in the 1935 seed plot seems best explained by the assumption that 2, or more, of the winged aphids found in the plot early in August had come to the seed plot as dispersal forms from diseased plants present in small numbers in other fields on this farm. All tubers planted in the 1935 seed plot came from a relatively small area in the 1934 seed plot. All tubers harvested, except those under an ounce in weight, were planted in 1935. Thus it seems logical to believe that the 7 tubers producing plants showing symptoms of mosaic came from not more than 2 plants and very likely came from 1 hill infected during 1934.

No aphids were observed in the 1935 seed plot until July 15 when 0.7 per cent of the leaves examined were found to be infested. Green peach aphids were first observed on July 22. At this time 4.4 per cent of the leaves examined were found to be infested by one or another species. Buckthorn aphids increased rapidly from this time. On August 6, 29 per cent of the leaves examined were infested and on August 20, 56.5 per cent. The infestation did not increase beyond this point. On September 20, although most of the foliage was dead, many buckthorn aphids were still to be found on the stalks. Some green peach aphids were also present, but almost no pink and green potato aphids were in evidence.

The infestation of buckthorn aphids was the heaviest that has been encountered on this farm. Even so, there were relatively

few winged dispersal forms produced, and there is no evidence that there was any field-to-field spread of virus.

Two small lots of seed were early harvested from the 1935 seed plot on August 2 and August 12. A third, and much larger, lot was taken on August 23, 1935.

1936. These 3 lots of seed were planted in a seed plot on May 14, 1936. Among the plants produced by tubers early harvested on August 2 and August 12 (3,180 hills planted in 1936) 4 hills showing symptoms of "weather mottle" were found. From the plants produced by tubers early harvested on August 24, 1935 (32,270 hills planted in 1936), 42 hills (0.14 per cent) showing symptoms of "weather mottle" were removed. No leaf roll or mosaic plants were taken from this plot, which was rogued 6 times during the summer (Table 42).

The pink and green potato aphid was found in the 1936 seed plot on July 6 at which time 0.45 per cent of the leaves examined were infested. The buckthorn aphid was present by July 14 when a single wingless individual was observed. The infestation had increased by this time to the point where aphids were found on 4.7 per cent of the leaves examined. On July 22 the first green peach aphids were discovered. By this time 13.3 per cent of the leaves examined were found to be infested. The infestation developed rapidly. By the first of August 40.2 per cent of the leaves examined were infested. By the 20th of August the figure had increased to 73.8 per cent. Shortly afterward the infestation diminished and with the dying of the foliage the aphids disappeared.

1937. Early harvesting was done again in August and enough seed was taken to plant the 1937 seed plot which was planted on May 15. The plot contained 48,600 hills. It was rogued 7 times during the summer (Table 42). On July 2, 12 hills with symptoms of a faint mosaic were removed. No leaf roll or mosaic plants were detected at any time during the season. On August 12, 4 hills showing symptoms of apical leaf roll [*Solanum virus* 17 of K. M. Smith (*39*, p. 389)] were removed. Since this virus disease was unknown in this seed stock previously, it would appear that it must have entered the seed plot during the previous summer. Seed stocks having plants infected with apical leaf roll were growing in 1936 about 500 yards from the 1936 seed plot.

Aphid records for 1937 indicate that the infestation reached

record proportions. While larger numbers of the pink and green potato aphid were recorded in 1932 and of buckthorn aphids in 1935, the totals of all aphids recorded were well below those of 1937 (Fig. 6).

The green peach aphid was observed in larger numbers than at any other time on this farm. At the peak of its infestation, the numbers recorded were on the average nearly 6 times as large as the previous high point recorded in 1932. Nineteen hundred thirty-seven is the first season during which, on this farm, these 3 aphid species developed in much the same manner and when all 3 approached similar numbers at the peak of the infestation.

Buckthorn aphids were first observed on July 2. At that time 1.3 per cent of the leaves examined were infested by aphids. A slight decrease to 1 per cent was noted on July 13. On July 27, 3.3 per cent of the leaves examined were infested. The infestation developed rapidly during August. Weather conditions were very favorable for aphid development. The fungus which usually attacks the aphids and materially reduces their numbers was not observed in the field in 1937. Although insect parasites and predators were unusually abundant, they were ineffective in reducing the aphid population until near the end of August. Even then many more aphids were to be found on the plants through the early part of September than have been found in previous seasons.

On August 12, 54.7 per cent of the leaves examined were infested and on August 24, 96.3 per cent. No larger percentage of leaves has been recorded as infested during this study.

1938. The season of 1938 was early, permitting planting of the seed plot on May 7, a full week earlier than had been possible before. Roguing was possible 8 days earlier than in any previous year. It proved possible to remove over 90 per cent of all plants showing symptoms of leaf roll before July 1. Plants having mosaic were not detected as early but were removed before the end of July (Table 42).

Plants showing symptoms of mosaic or leaf roll had not been found in this seed stock in either 1937 or 1936. It seems evident, therefore, that, during the season of 1937, the viruses producing these diseases must have entered the seed plot. Plants having mosaic were found in small numbers in a commercial field 400 yards west of the seed plot. Plants having leaf roll were present

early in the season in a Cobbler seed plot 500 yards north of the Green Mountain seed plot. Open fields appear to have provided insufficient isolation from potatoes among which were a few diseased hills.

Most of the seed planted in 1938 was early harvested on August 15, 1937. The aphid index at that time was high (Fig. 6). Since the amount of disease found in this seed stock was low, it would seem evident that the number of hills becoming infected as a result of the spread of virus from fields at a distance from the seed plot was not large. Following the infection of these few hills, aphids, present in large numbers in the seed plot, continued to bring about spread of virus from hill to hill within the seed plot. This was especially true of the leaf roll virus. Most of this hill-to-hill spread took place in the latter part of August or in September. Of the plants growing in 1938 from tubers harvested at the usual time from the 1937 seed plot, nearly 3 per cent showed symptoms of leaf roll and an additional 1 per cent showed symptoms of mosaic.

Perhaps the most important factor influencing the results obtained at this center is isolation from badly diseased potatoes that were unrogued throughout the growing season. This belief is strengthened by the results obtained elsewhere where various viruses entered seed stocks previously free from plants showing symptoms of those particular diseases.

Adequate isolation from diseased seed stocks limits infection of healthy hills to the spread of virus from one hill to another in the seed plot. Actually, isolation of the seed plots on this farm has not been perfect because of the fact that for each acre in the seed plot there have been approximately 17 acres in commercial plantings. While the number of diseased plants in these fields has been small and, until 1938, progressively smaller, and planting has been done by tuber units so that careful roguing was possible throughout July and August each season, enough diseased plants have been present so that there was always a chance that the causal agents of mosaic and leaf roll might enter the seed plot. The virus producing mosaic actually did enter, presumably from commercial fields, during the summer of 1934 and again during 1937. Isolation in this case was sufficient to prevent spread of the causal agents of mosaic and leaf roll from farm to farm but apparently not sufficient, in the case of the seed plot, to absolutely prevent field-to-field spread on

this farm in certain years. Such field-to-field spread of the viruses producing mosaic and leaf roll was very much less than occurred elsewhere in Aroostook County and has not, as yet, seriously affected the results obtained at Masardis—at least from a practical standpoint.

The writer is fully in accord with the view expressed by Folsom, Schultz, and Bonde (*17*, p. 58), and by Davies and Whitehead (*11*, p. 555) that, although field-to-field spread of virus may be negligible in amount, it is potentially dangerous because virus brought in by relatively few winged aphids may be spread subsequently within the planting by wingless forms. While Davies and Whitehead were dealing with leaf roll, there seems to be no reason why, under the conditions existing in Aroostook County, mosaic and other virus diseases cannot be included in this idea.

Spread of virus from hill to hill within a seed plot is influenced by date of planting, which governs dates of roguing, and by the percentage of diseased hills present. On this farm, mosaic and leaf roll plants have never exceeded 0.6 per cent of those growing. In the strain of Green Mountain, from which both leaf roll and mosaic plants were eliminated, leaf roll plants have not exceeded 0.19 per cent and mosaic plants 0.08 per cent of those growing (Table 41). Conditions here were thus favorable for thorough roguing before the aphids became numerous. All plants showing symptoms of leaf roll or of mosaic have been removed before August 2 and, since 1934, before July 20 (Table 42). Aphids have been present before these dates, but aphid dispersal within the seed plots has not been evident until later in the season.

When aphids are scarce or the infestation develops slowly, diseased plants can be removed from isolated seed plots early enough so that conditions that favor spread of virus do not develop even though large aphid populations may be present in August. When, as in 1937, spread of virus occurs before diseased plants can be removed, secondary spread from plants inoculated during the current season will be brought about by infestations developing toward the end of the season.

Over a period of years the relative abundance of particular species of aphids has varied as have the numbers of winged aphids.

Among the factors contributing to the elimination of leaf roll and mosaic in particular instances have been isolation from unrogued diseased fields, early planting (Table 41), early, careful

roguing (Fig. 6), delayed aphid infestation in 1933 and 1935 (Tables 43-47), few aphids in 1934 (Fig. 6), early harvesting of seed for each succeeding seed plot (Fig. 6), and weather conditions such that mosaic was distinctly visible early in the season in 1933 and 1935.

In certain years, when insects are abundant, unusual precautions must be taken to insure adequate isolation of seed plots from commercial fields if field-to-field spread of virus is to be avoided.

CONCLUSIONS ON THE EXPERIMENTAL RESULTS OBTAINED AT MASARDIS

The record indicates that this was a successful center.

Favorable factors included isolation adequate to prevent farm-to-farm spread of virus, small percentage of diseased plants originally present, early planting after 1933, early roguing, adequate expression of disease symptoms, opportunity to select seed for the following year's seed plot from areas in the current plot from which no diseased plants had been removed during the current season, early harvesting of seed for succeeding seed plots, and careful roguing of commercial fields on the farm.

Unfavorable factors included isolation of seed plots from commercial fields inadequate to prevent field-to-field spread of virus in some seasons, planting of more than one variety of potatoes on the farm, early aphid infestation in some seasons, and late frosts.

A COMPARISON OF THE RESULTS OBTAINED AT DIFFERENT LOCATIONS

In addition to the 7 locations described in detail, plots were established also, for various periods of time, at 7 additional centers. None of these centers was successful. All were similar to one or another of the centers described and so have not been included in this discussion. While it is obviously impossible to make direct comparisons between plots, because not all of the variables can be controlled, some points of similarity or dissimilarity can be discovered.

EFFECT OF INADEQUATE ISOLATION

In none of the centers studied was isolation from other seed stocks sufficient to prevent spread of virus into the experimental seed plot, at least in some seasons. Field-to-field spread of virus was least at Masardis and Benedicta where plots were so well isolated from other farms that centers of infection were confined to the potatoes planted on these farms. There is no reason to believe that the results actually obtained could have been accomplished if the commercial fields on these farms had been planted with table stock or with inadequately rogued, certified seed. There is evidence that at Masardis, in some seasons, there will be enough spread of virus from carefully rogued fields to produce a serious situation in the seed stocks to be used the following year.

In the other experimental locations, there has been, in certain instances (New Canada, for example), definite evidence of field-to-field spread of virus. Where definite proof of such spread is lacking, the unsuccessful handling of the seed plots is best explained on the assumption that field-to-field spread of virus did occur but that it was, in these cases, limited to types of disease already present and so not distinguishable, as was possible in other cases.

EFFECT OF EARLY PLANTING

The time of planting of a seed plot is one of the most important considerations in the handling of foundation seed, unless special circumstances (as at Woodland) influence results.

In this connection, the record at Masardis is interesting. In 1931, 1932, and 1933 planting was delayed because of land clearing operations. The seed planted in 1931 was more nearly free from mosaic than that imported in 1933, yet there was an increase in mosaic in the years after 1931. In the years following 1933, when early planting became possible, there was a decrease in mosaic until 1937 reversed the trend. Date of planting was not the only known variable so does not account for the entire difference.

At Benedicta early planting was possible every year. Results were satisfactory until 1937 when leaf roll spread considerably.

At the other locations late planting was the rule and the results were unsatisfactory. There were a few exceptions as, for example, the 1934 plot at New Canada followed in 1935 by a re-

duction in the amount of mosaic and leaf roll found. Another exception is found in the 1934 plot at Spaulding where early planting was associated with a reduction in total disease content in 1935.

Early planting at Woodland was found to be undesirable because of early infestations by buckthorn aphids, a fact not offset by an ability to rogue early.

The value in early planting lies in its relation to other factors in seed plot management. Germination is hastened and the development of foliage, on which diagnosis of disease symptoms depends, takes place earlier in the season, thus making it possible to remove infection centers before aphids are numerous and so reducing or even eliminating hill-to-hill spread of virus. Tuber development is likely to take place rapidly enough so that early harvesting may be done by the middle of August, a date ordinarily early enough to avoid considerable late season spread of virus.

EFFECT OF TIME OF ROGUING

No specific study was made of this factor but some incidental information has been obtained because it has been found to be impossible to eliminate all diseased plants during the early part of the season. Consequently, in practice, roguing has been done at intervals throughout the season.

The information available indicates that, in most years and in most of those localities studied, roguing cannot be done early enough to prevent some spread of virus from diseased units.

EFFECT OF EARLY APHID INFESTATION

It has been found repeatedly that late infestations are likely to be initiated by dispersal forms and that they may introduce virus into the seed plot if they have fed upon infected potatoes. Infestations that develop rapidly early in the season may be even more likely to bring about the spread of virus (Woodland). The most favorable situation seems to be one in which the infestation is initiated by migrant forms coming to potatoes at an early date and developing there slowly. This, fortunately, is the usual course of events in seed plots located in otherwise favorable situations. If the number of tubers producing plants showing symptoms of mo-

saic or leaf roll is small and roguing is possible late in June or early in July, a normally developing aphid infestation starting late in June will bring about relatively little spread of virus, and this may be avoided in large measure in the subsequent seed plot by judicious selection of seed about the middle of August.

RECOMMENDATIONS FOR THE MAINTENANCE OF GREEN MOUNTAIN SEED STOCKS IN NORTHERN MAINE

The practical application of the information obtained in connection with this research project should make possible the indefinite propagation of Green Mountain seed stocks in Northern Maine.

While it is not believed to be essential to ultimate success, it is far easier to start a seed project with stock containing but a trace of the virus producing mild mosaic or of that producing leaf roll. Such stocks are readily available at the present time.

The seed stock must be planted in an isolated location so that it will be protected against field-to-field spread of virus during the growing season.

Planting must be done early, certainly before May 20, so that roguing will be possible in the early part of July and early harvesting by the middle of August. Planting by tuber units is necessary to aid in roguing.

Roguing must be done carefully, thoroughly, and frequently during July and August. The roguing done during the first 2 weeks of July will be the most effective. Careful disposal of diseased plants, seed pieces, and tubers is essential.

Early harvesting of enough seed to plant the succeeding seed plot completes the season's activities and, if carefully done, insures satisfactory seed stocks for the following year.

SUMMARY

1. On the basis of average sales of certified seed for the years 1933 to 1937, a need for 67,000 barrels of foundation seed each year in Maine is indicated.

2. The experimental work reported upon was conducted in Aroostook County, Maine, utilizing seed stocks of the Green Moun-

tain variety. What can be accomplished with this variety can be done more easily with other varieties, in the light of past experience.

3. Mild mosaic is the most troublesome of the virus diseases of Green Mountains. Occasionally, leaf roll (and net necrosis) becomes a major problem.

4. Four species of aphids are found more or less commonly on potatoes in Aroostook County. These are (1) the green peach aphid, *Myzus persicae* Sulz., (2) the foxglove aphid, *M. pseudosolani* Theob., (3) the pink and green potato aphid, *Macrosiphum solanifolii* Ashm., and (4) the buckthorn aphid, *Aphis abbreviata* Patch.

5. Some apparent differences in the distribution of the four common aphids on potatoes were found. These differences appear to be due, in part at least, to differences in the geographical relationship of seed plots to primary aphid host plants.

6. The date of planting of a seed plot influences the subsequent aphid infestation. Early planted plots are infested before late planted plots.

7. Infestations of early planted plots are almost invariably initiated by winged migrants, while in late planted plots the infestation is initiated, in most cases, by dispersal forms.

8. A numerical study of aphid populations in seed plots has indicated that the green peach aphid is more numerous in years when excessive spread of virus occurs than in years when it does not occur.

9. In the experimental seed plots, marked increase in the number of diseased tubers present in a rogued seed stock occurred only in late planted plots or in years following a season when the index figure for the green peach aphid reached a high level.

10. Detailed observations on the relation of the insect population of the seed plots to the spread of virus is presented for 7 centers. Two of these 7 centers were found to be satisfactory, in most seasons, for the propagation of foundation seed stock.

11. Inadequate isolation of seed plots from other potatoes resulted in unsatisfactory seed stocks. In no case studied was the isolation of the seed plot sufficient, in all years, to prevent field-to-field spread of virus.

12. Early roguing of plants showing symptoms of virus diseases usually removes infection centers before plant lice become

numerous. Early roguing is most effective where isolation is adequate.

13. Foundation Green Mountain seed stocks may be propagated indefinitely in Aroostook County. To this end isolation must be adequate to eliminate field-to-field spread of virus. Planting must be done early, certainly before commercial stocks are planted. Roguing, in tuber unit plantings, must be practiced early and often. Seed for subsequent seed plots must be judiciously selected about the middle of August in normal seasons.

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EXPLANATION OF FIGURES

The six figures on the following pages are included to give a graphic representation of several interrelated factors affecting seed plots.

An attempt has been made to illustrate the relationship between roguing and early harvesting and the aphid population as it affects the spread of disease. The relationships should be viewed in connection with the text in order to take into account the effect of isolation which does not lend itself to graphic illustration.

The symbols used include "L" for leaf roll plants removed; "M" for mosaic plants removed; and "E" for early harvest dates.

The representation of the aphid infestation is based on the index figures presented elsewhere in tables. The points plotted were determined from the index figures by taking the cube root of the actual figures. This was done so that the resulting graphs could be printed on one page.

The graphs representing disease are presented by plotting the percentage figures presented elsewhere in tables.

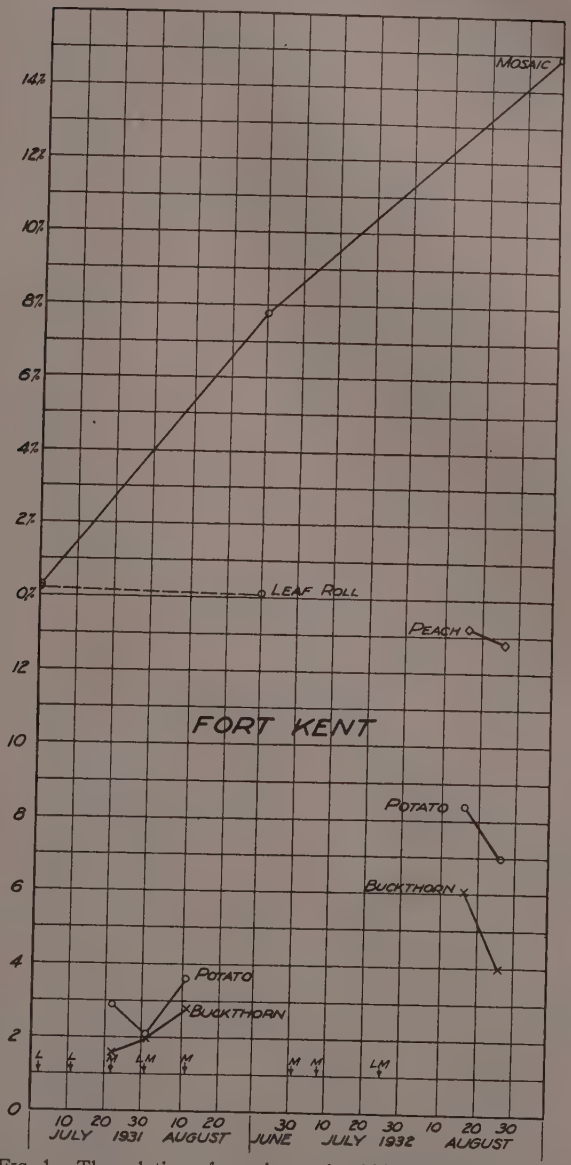

FIG. 1. The relation of roguing and aphid population to the spread of disease at Fort Kent 1931-1932. (For explanation of symbols, etc., see page 262.)

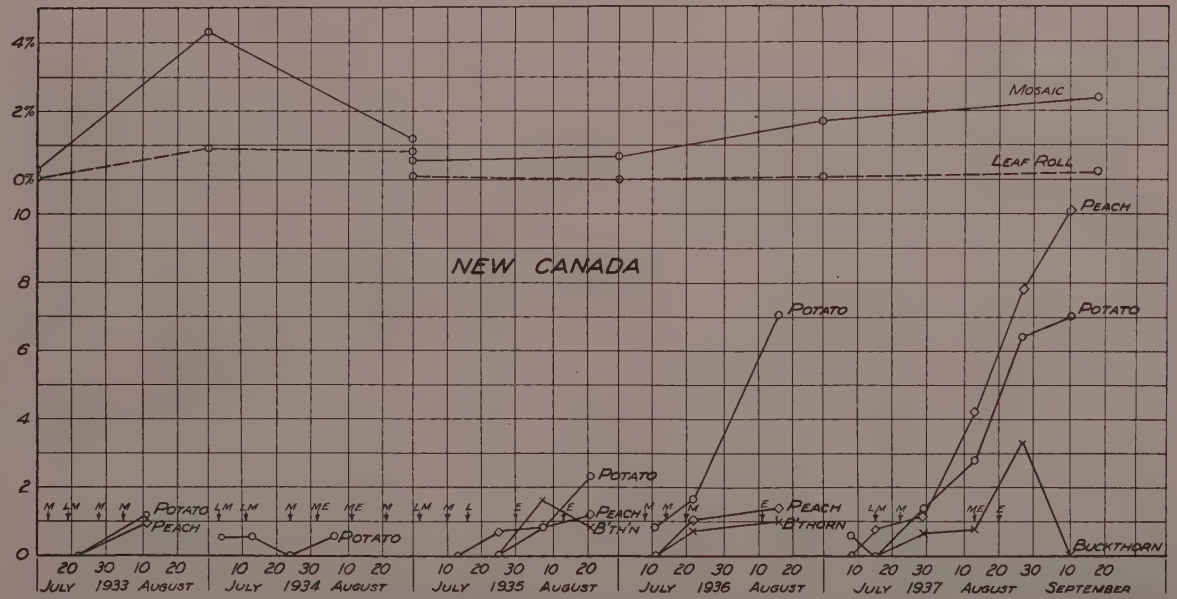

FIG. 2. The relation of roguing, aphid population and early harvesting to the spread of disease at New Canada 1933-1938.
(For explanation of symbols, etc., see page 262.)

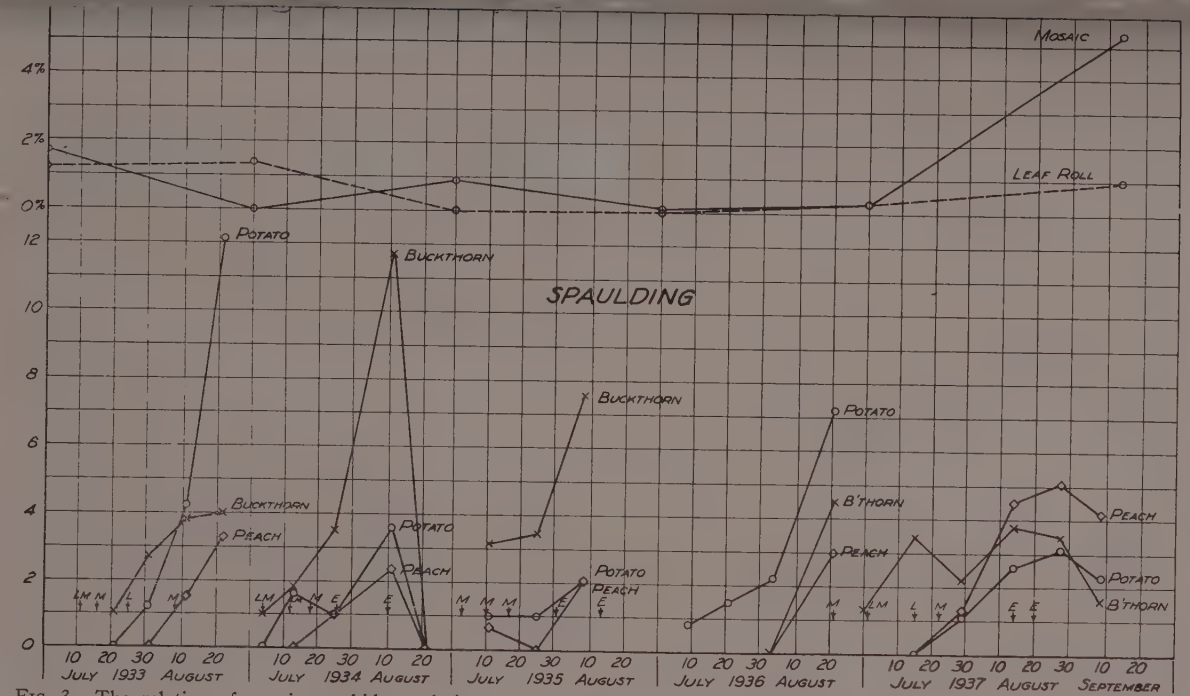

FIG. 3. The relation of roguing, aphid population and early harvesting to the spread of disease at Spaulding 1932-1938. (For explanation of symbols, etc., see page 262.)

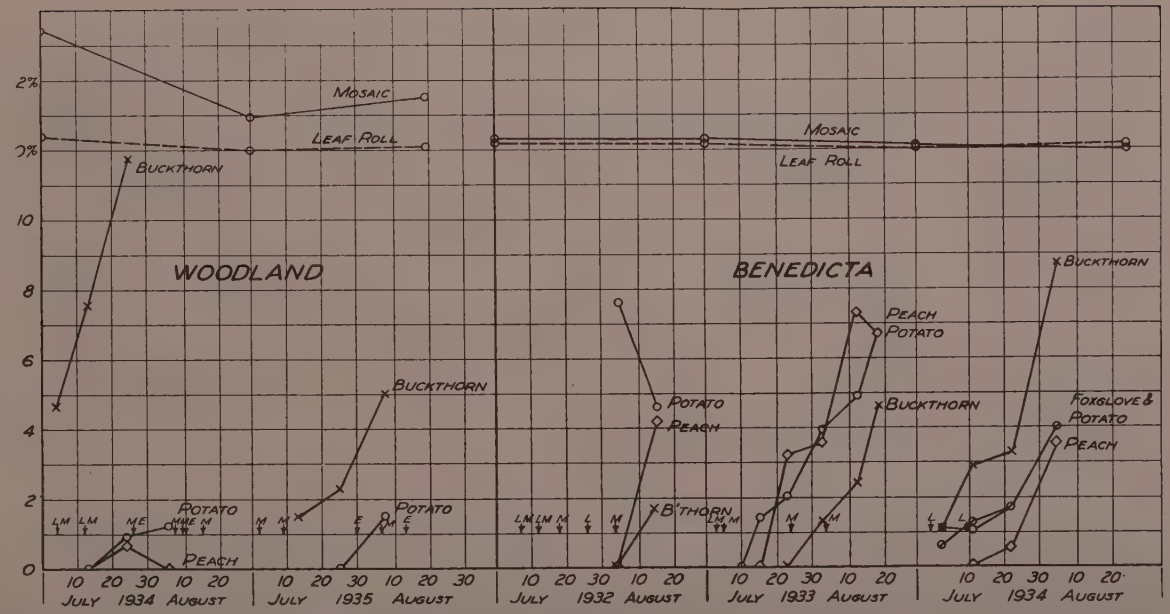

FIG. 4. The relation of roguing and aphid population to the spread of disease at Woodland 1934-1935 and at Benedicta 1931-1934. (For explanation of symbols, etc., see page 262.)

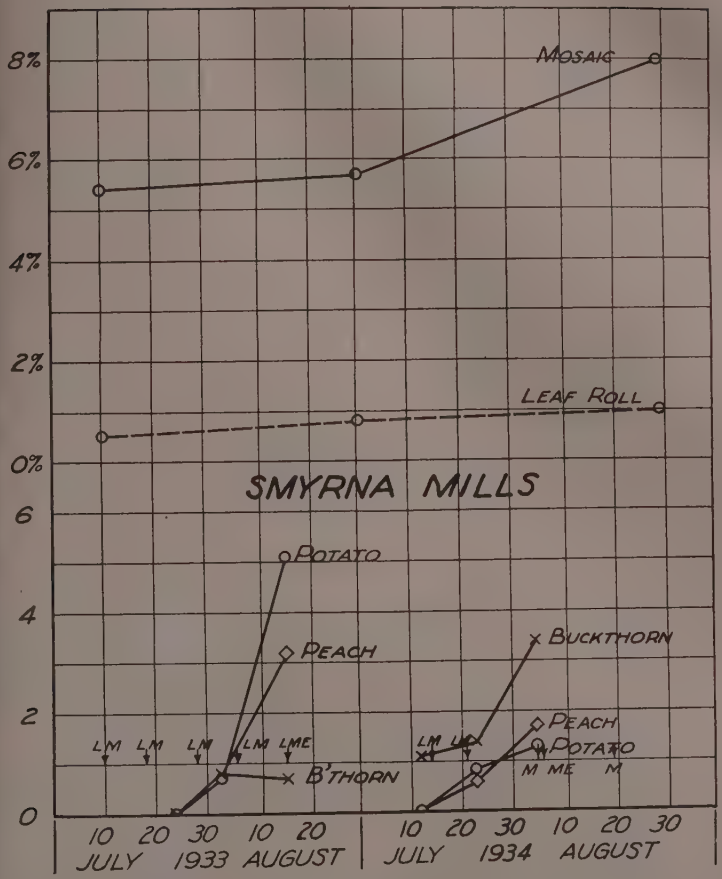

FIG. 5. The relation of roguing, aphid population and early harvesting to the spread of disease at Smyrna Mills 1933-1934. (For explanation of symbols, etc., see page 262.)

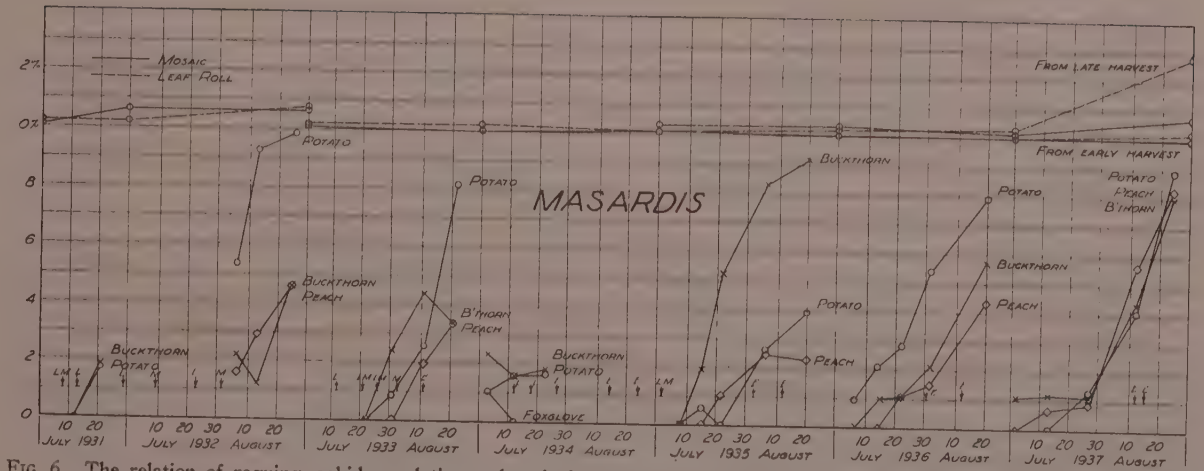

FIG. 6. The relation of roguing, aphid population and early harvesting to the spread of disease at Masardis 1931-1938. (For explanation of symbols, etc., see page 262.)

TABLE 1

*Acreage Entered and Passed and Sales of Maine Certified Seed Potatoes—1922–1938**

Year	Total acreage entered	Total acreage passed	Total sales
			Barrels
1922	4,024	1,189	43,768
1923	13,056	6,228	276,280
1924	25,417	14,699	604,079
1925	18,311	7,065	419,397
1926	11,289	6,655	512,123
1927	18,332	10,781½	694,819
1928	26,360	16,846	645,028
1929	15,529	10,799	555,094
1930	13,096¾	9,370½	518,819
1931	15,344	14,204½	700,923½
1932	11,681	9,850¾	654,010½
1933	14,134½	12,039¾	824,048
1934	18,896½	16,006¾	1,031,880
1935	25,910	20,165	954,534
1936	22,583¾	18,084	1,258,704
1937	29,768	25,717	1,293,464
1938	31,312½	13,752¼	

* Figures supplied by E. L. Newdick, State Department of Agriculture, Augusta, Maine.

TABLE 2

*Potato Production in the United States, in Maine, and in Aroostook County, 1922–1938**

Year	United States	Maine	Aroostock† County
	thousands of bushels	thousands of bushels	thousands of bushels
1922	419,288	25,500	21,430
1923	366,356	31,720	25,684
1924	384,166	40,848	34,075
1925	296,466	31,500	26,561
1926	321,607	35,625	29,102
1927	369,644	36,110	30,318
1928	427,249	38,720	32,649
1929	332,204	48,472	42,791
1930	340,572	44,750	37,120
1931	384,125	47,988	42,370
1932	376,425	40,460	32,910
1933	342,306	42,000	34,407
1934	406,105	55,404	46,933
1935	387,678	38,880	33,231
1936	331,918	45,885	38,680
1937	394,139	47,600	40,649
1938	369,297	39,600	

* Figures supplied by the Department of Agricultural Economics.
† Aroostook production revised on basis of ratio of unrevised Aroostook production to unrevised Maine production.

TABLE 3

Relation of Date of Planting to Initial Infestation at Seven Centers in Aroostook County, Maine—1931–1938

Locality	Masardis		Spaulding		Benedicta		New Canada		Smyrna Mills		Woodland		Fort Kent	
Year	Date of planting	First aphid record	Date of planting	First aphid record	Date of planting	First aphid record	Date of planting	First aphid record	Date of planting	First aphid record	Date of planting	First aphid record	Date of planting	First aphid record
1931	6-9	7-21	6-12	7-22	5-15	7-3							Late May	7-1
1932	6-7	7-15	6-1	*	5-19	7-5							Late May	6-2
1933	6-2	7-21	6-2	7-21	5-7	7-15	6-1	8-11	6-5	8-2				
1934	5-14	7-6	5-11	7-4	5-10	7-2	6-5	7-4	6-3	7-12	5-18	7-4		
1935	5-16	7-15	5-30	7-11			6-2	7-25			5-20	7-13		
1936	5-14	7-6	6-6	7-21			6-5	7-21						
1937	5-15	7-2	6-2	6-30			6-2	7-8						
1938	5-7	6-23					6-1	8-1						

* No record.

TABLE 4

Date of Planting, Size of Plot and Diseased Hills Removed from Successive Seed Plots Rogued at Fort Kent—1931–1932

Year	Date of planting	Total hills in plot	Mild mosaic		Leaf roll		Crinkle mosaic	
			Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed
1931	Late May	10,464	24	0.2	28	0.3	0	0
1932	Late May	9,612	82	0.9	4	0.1	248	6.9

TABLE 5

Diseased Hills Removed and Dates of Roguing—Fort Kent—1931–1932

Year and disease	Hills removed because of various diseases on different dates					
1931	7-2*	7-11*	7-14*	7-22*	7-31*	8-11*
Mosaic	0	0	4	8	4	8
Leaf roll	20	4	0	0	4	4
1932	7-1*	7-8*	7-25*			
Mosaic	4	28	0			
Crinkle mosaic	0	0	248			
Leaf roll	0	0	4			

* Rogued by Geddes Simpson.
* Rogued by Donald Folsom.

TABLE 6

Aphid Population Counts—Fort Kent—1931–1932

Year and species	First aphid record	First count												Second count										Third count									
		All forms						Winged forms						All forms						Winged forms						All forms						Winged forms			
		Date	No.	Range[4]	Index[5]	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
(all spp.)		7-22	159	?	28.9	540[6] ?	?	0	0	0	0	0	0	7-31	48	?	17.8	270 ?	?	0	0	0	0	0	0	8-11	100	?	66.7	150 ?	?	0	0	0	0	0	0
	7-14		136	?	24.6	?	?	0	0	0	0	0	0		26	?	9.6	?	?	0	0	0	0	0	0		68	?	45.3	?	?	0	0	0	0	0	0
[3]	7-22		23	?	4.3	?	?	0	0	0	0	0	0		22	?	8.1	?	?	0	0	0	0	0	0		32	?	21.3	?	?	0	0	0	0	0	0
(all spp.)		8-16	1,778	0-340	3,119.3	57 53	92.98	6	10.5	0.34	0-2	4	7.02	8-26	1,443	0-175	2,531.6	57 51	89.47	5	8.8	0.35	0-1	5	8.77											
	6-25		339	0-31	594.7	49	85.96	6	10.5	1.80	0-2	4	7.02		206	0-55	361.4	41	71.92	3	5.3	1.46	0-1	3	5.26											
[3]	7-24		1,311	0-340	2,300.0	31	54.39	0	0	0	0	0	0		1,201	0-175	2,107.0	39	68.42	0	0	0	0	0	0											
	7-24		128	0-62	224.6	6	10.53	0	0	0	0	0	0		36	0-9	63.2	7	12.28	2	3.5	5.56	0-1	2	3.51											

acrosiphum solanifolii, pink and green potato aphid.
phis abbreviata, buckthorn aphid.
yzus persicae, peach aphid.
epresents the greatest variation in numbers of aphids found on individual leaves.
verage number of aphids on one hundred leaves.
igure in italics represents number of leaves examined; lower figures, number of leaves infested.

TABLE 7

Date of Roguing and Injection of Hills Adjacent to Mosaic Hills Removed at Fort Kent—1931–1932

1931	7-14	7-25	7-31	8-11
Total number of tubers harvested from hills adjacent to units removed	45 (20 hills)	67 (20 hills)	98 (20 hills)	46 (20 hills)
Total number of tubers producing mosaic plants in 1932	7	4	11	6
1932	7-11	7-8	7-25	
Total number of tubers harvested from hills adjacent to units removed	151 (20 hills)	129 (20 hills)	245 (60 hills)	
Total number of tubers producing mosaic* plants in 1933	1	20	36	

* Mild and crinkle.

TABLE 8

Date of Planting, Size of Plot and Diseased Hills Removed from Seed Plots Rogued at New Canada—1933–1938

Year	Dates of planting	Total hills in plot	Mild mosaic		Leaf roll		Crinkle mosaic		Rugose mosaic		Weather mottle		Giant hill		Blackleg		Verticillium wilt	
			Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed
1933	6-1	3,426	11	0.32	1	0.03	0	0	0	0	0	0	0	0	0	0	0	0
1934	5-16	6,620	288	4.4	60	0.91	64	0.97	60	0.91	40	0.06	28	0.4	0	0	28	0.4
1935	6-2	5,082	58	1.14	4	0.8	12	0.24	0	0	35	0.69	0	0	0	0	0	0
1935	6-2	11,870*	62	0.52	8	0.07	12	0.1	0	0	51	0.43	0	0	0	0	0	0
1936	6-5	6,750	43	0.64	0	0	0	0	0	0	4	0.06	0	0	289	4.28	0	0
1937	6-2	10,416	179	1.72	12	0.12	62	0.6	8	0.08	4	0.04	0	0	0	0	0	0
1938	6-1	9,650	227	2.35	24	0.25	24	0.25	12	0.12	0	0	0	0	0	0	0	0

* Including hills planted with seed stocks introduced in 1935.

TABLE 9

Diseased Hills Removed and Dates of Roguing—New Canada—1933–1938

Year and disease	Hills removed because of various diseases on different dates							
1933*	7-13	7-19	7-28	8-4				
Mild mosaic	12	24	4	4				
Leaf roll	0	4	0	0				
1934*	7-3	7-11	7-17	7-24	8-1	8-11	8-21	
Mild mosaic	180	60	0	8	16	4	1†	
Crinkle mosaic	84	0	0	0	0	0	0	
Rugose mosaic	60	0	0	0	0	0	0	
Weather mottle	0	8	0	28	4	0	0	
Leaf roll	44	16	0	0	0	0	0	
Giant hill	0	0	0	0	0	8	20	
Verticillium wilt	0	0	0	0	0	12	16	
1935*	7-2	7-10	7-16	7-23	7-30	8-5	8-13	8-21
Mild mosaic	36	26	0	0	0	0	0	0
Crinkle mosaic	12	0	0	0	0	0	0	0
Weather mottle	0	0	12	11	8	20	0	0
Leaf roll	4	0	4	0	0	0	0	0
1936*	7-18	7-24	7-30	8-6	8-14	8-21	8-28	
Mild mosaic	40	1	2	0	0	0	0	0
Weather mottle	0	4	0	0	0	0	0	0
Leaf roll	0	0	0	0	0	0	0	0
1937*	7-15	7-22	7-29	8-6	8-13			
Mild mosaic	163	12	0	0	4†			
Crinkle mosaic	62	0	0	0	0			
Rugose mosaic	8	0	0	0	0			
Weather mottle	4	0	0	0	0			
Leaf roll	12	0	0	0	0			
1938*	7-14	7-21	8-1	8-16				
Mild mosaic	194	33	0	0				
Crinkle mosaic	24	0	0	0				
Rugose mosaic	12	0	0	0				
Leaf roll	24	0	0	0				

* Rogued by Wesley Porter.
† Current season infection.
* Figures refer to the diseased hills removed from among the total number of hills planted in 1935.

TABLE 10

Aphid Population Counts—New Canada—1933–1937

ear nd ieles	First aphid record	First count											
		All forms						Winged forms					
		Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
(all p.)		7-22	0	0	0	*300* 0	0	0	0	0	0	0	0
	8-11		0	0	0	0	0	0	0	0	0	0	0
	8-11		0	0	0	0	0	0	0	0	0	0	0
(all).)		7-4	1	0-1	0.2	*501* 1	0.2	1	0.2	100.00	0-1	1	0.2
	7-4		1	0-1	0.2	1	0.2	1	0.2	100.00	0-1	1	0.2
	8-11		0	0	0	0	0	0	0	0	0	0	0
(all).)		7-13	0	0	0	*315* 0	0	0	0	0	0	0	0
	8-7		0	0	0	0	0	0	0	0	0	0	0
	7-25		0	0	0	0	0	0	0	0	0	0	0
	8-7		0	0	0	0	0	0	0	0	0	0	0
(all).)		7-21	2	0-1	0.6	*324* 2	0.62	0	0	0	0	0	0
	7-21		2	0-1	0.6	2	0.62	0	0	0	0	0	0
	8-1		0	0	0	0	0	0	0	0	0	0	0
	8-1		0	0	0	0	0	0	0	0	0	0	0
(all).)		7-8	2	0-1	0.6	*315* 2	0.63	2	0.6	100.00	0-1	2	0.63
	7-8		1	0-1	0.3	1	0.32	1	0.3	100.00	0-1	1	0.32
	7-15		0	0	0	0	0	0	0	0	0	0	0
	7-8		1	0-1	0.3	1	0.32	1	0.3	100.00	0-1	1	0.32

TABLE 11

Aphid Population Counts—New Canada—1933–1937

Year and species	Second count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	
1933 (all spp.)	8-11	10	0-6	2.8	*360* 5	1.39	5	1.4	50.00	0-1	5	
M s		6	0-6	1.7	1	0.28	1	0.3	16.66	0-1	1	
M p		4	0-1	1.1	4	1.11	4	1.1	100.00	0-1	4	
1934 (all spp.)	7-13	1	0-1	0.2	*489* 1	0.20	1	0.2	100.00	0-1	1	
M s		1	0-1	0.2	1	0.20	1	0.2	100.00	0-1	1	
1935 (all spp.)	7-25	1	0-1	0.3	*415* 1	0.25	1	0.3	100.00	0-1	1	
M p		1	0-1	0.3	1	0.25	1	0.3	100.00	0-1	1	
1936 (all spp.)	8-1	17	0-3	5.2	*324* 12	3.70	3	0.9	17.65	0-1	3	
M s		13	0-3	4.0	8	2.47	0	0	0	0	0	
M p		3	0-1	0.9	3	0.93	2	0.6	66.66	0-1	2	
A a		1	0-1	0.3	1	0.31	1	0.3	100.00	0-1	1	
1937 (all spp.)	7-15	2	0-1	0.6	*315* 2	0.63	0	0	0	0	0	
M p		2	0-1	0.6	2	0.63	0	0	0	0	0	

TABLE 12

Aphid Population Counts—New Canada—1933–1937

Year and species	Third count												
	All forms						Winged forms						
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
(all spp.)	8-22	Present Present					Present					
	7-24	0	0	0	*486* 0	0	0	0	0	0	0	0
(all spp.)	8-7	10	0-4	4.9	*206* 3	1.46	1	0.5	10.00	0-1	1	0.49
		1	0-1	0.5	1	0.49	0	0	0	0	0	0
		1	0-1	0.5	1	0.49	1	0.5	100.00	0-1	1	0.49
		8	0-4	3.9	2	0.97	0	0	0	0	0	0
(all spp.)	8-26	1,147	0-39	354.0	*324* 225	69.44	35	10.8	3.05	0-1	35	10.80
		1,136	0-39	350.6	225	69.44	34	10.5	2.99	0-1	34	10.49
		8	0-3	2.5	4	1.23	0	0	0	0	0	0
		3	0-3	0.9	1	0.31	1	0.3	33.33	0-1	1	0.31
(all spp.)	7-29	14	0-4	4.4	*315* 11	3.49	1	0.3	7.14	0-1	1	0.32
		8	0-1	2.5	8	2.54	1	0.3	12.50	0-1	1	0.32
		5	0-4	1.6	2	0.63	0	0	0	0	0	0
		1	0-1	0.3	1	0.32	0	0	0	0	0	0

o count made. The pink and green potato aphid was more numerous than the peach aphid. The buckthorn aphid was not found.

TABLE 13

Aphid Population Counts—New Canada—1934–1937

Year and species	Fourth count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
(all spp.)	8-6	1	0-1	0.2	*459* 1	0.22	0	0	0	0	0	0
		1	0-1	0.2	1	0.22	0	0	0	0	0	0
(all spp.)	8-21	30	0-4	14.6	*206* 19	9.22	0	0	0	0	0	0
		25	0-4	12.1	15	7.28	0	0	0	0	0	0
		4	0-2	1.9	3	1.46	0	0	0	0	0	0
		1	0-1	0.5	1	0.49	0	0	0	0	0	0
(all spp.)	8-18	319	0-13	98.4	*315* 99	31.43	6	1.9	1.94	0-1	6	1.90
		72	0-9	22.9	42	13.33	0	0	0	0	0	0
		236	0-13	74.9	76	24.13	6	1.9	2.54	0-1	6	1.90
		2	0-1	0.6	2	0.63	0	0	0	0	0	0

TABLE 14

Aphid Population Counts—New Canada—1934-1937

Year and species	Fifth count												
	All forms						Winged forms						P ce lea h fes
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested		
1934	8-11	Present in small numbers						Present					
1937 (all spp.)	8-27	2,442	0-36	775.2	315 293	93.02	4	1.3	0.16	0-1	4		1
M s		831	0-26	263.8	223	70.79	3	0.95	0.36	0-1	3		0
M p		1,494	0-36	474.3	226	71.75	0	0	0	0	0		0
A a		117	0-35	37.1	19	6.03	1	0.3	0.85	0-1	1		0

Year and species	Sixth count												
	All forms						Winged forms						P ce lea h fes
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested		
1934 (all spp.)	8-21												
M s		Present					Present						
M p		Present					Present						
1937 (all spp.)	9-10	4,074	0-75	1,371.7	277 269	90.57	95	32.0	2.33	0-4	61		2
M s		1,000	0-20	336.7	199	67.00	66	22.2	6.66	0-4	48		1
M p		3,074	0-75	1,035.0	238	80.13	29	9.8	0.94	0-2	24		8

TABLE 15

Date of Roguing and Infection of Hills Adjacent to Mosaic Hills Removed New Canada

1933	7-13	8-4			
Total number of tubers harvested from hills adjacent to units removed	197 (20 hills)	80 (10 hills)			
Total number of tubers producing mosaic* plants in 1934	12	0			
1934	7-3	7-11	7-24	8-1	
Total number of tubers harvested from hills adjacent to units removed	150 (20 hills)	157 (20 hills)	55 (10 hills)	149 (20 hills)	
Total number of tubers producing mosaic plants in 1935	0	6	0	1	
1935	7-2	7-10	8-6		
Total number of tubers harvested from hills adjacent to units removed	145 (30 hills)	175 (37 hills)	80 (20 hills)		
Total number of tubers producing mosaic plants in 1936	0	0	5		
1936	7-17	7-24	7-30	8-1	8-28
Total number of tubers harvested from hills adjacent to units removed	132 (20 hills)	125 (10 hills)	28 (2 hills)	32 (6 hills)	104 (10 hills)
Total number of tubers producing mosaic plants in 1937	0	0	0	2	6
1937	7-15	7-22	8-26		
Total number of tubers harvested from hills adjacent to units removed	503 (74 hills)	98 (20 hills)	23 (6 hills)		
Total number of tubers producing mosaic* plants in 1938	38	11	6		

* Mild and crinkle.

TABLE 16

Date of Planting, Size of Plot and Diseased Plants Removed from Seed Plots Rogi at Spaulding, 1932–1938

Year	Date of planting	Total hills in plot	Mild mosaic		Leaf roll		Crinkle mosaic		Weather mottle		Spindle tuber		Giant hi	
			Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	P ce re mo
1931	6-12		Discontinued in July because more than five per cent of the plants had b removed as diseased.											
1932	6-1	3,140	39	1.2	4	0.1	0	0	8	0.2	0	0	0	0
		1,804	48	2.7	8	0.4	130	7.2	0	0	0	0	0	0
1933	6-2	936	16	1.7	0	0	0	0	0	0	0	0	0	0
		1,684	40	2.4	12	0.7	0	0	0	0	0	0	12	0
1934	5-11	568	0	0	8	1.4	0	0	24	4.2	0	0	0	0
		1,160	24	2.1	12	1.0	0	0	0	0	12	1.0	16	1
1935	5-30	3,260	28	0.9	0	0	0	0	0	0	0	0	0	0
1936	6-6	3,460	2*	0.1	0	0	0	0	13	0.4	0	0	12	0
1937	6-2	8,450	22	0.3	24	0.3	0	0	8	0.1	0	0	0	0
1938			A representative sample from 50 barrels gave a reading of 5.4% mosaic and 1.(leaf roll.											

* Current season infection—symptoms visible in top leaves only.

TABLE 17

Diseased Hills Removed and Dates of Roguing—Spaulding—1932–1937

Year and disease	Hills removed because of various diseases on different dates						
1932†	7-4	7-11	7-22	8-6			
Mild mosaic	0	68	14	5			
Leaf roll	0	0	12	0			
Crinkle mosaic	96	31	3	0			
Weather mottle	0	8	0	0			
1933*	7-11	7-16	7-25	8-8			
Mild mosaic	28	20	0	8			
Leaf roll	4	0	4	0			
Giant hill	0	0	0	0			
1934*	7-4	7-12	7-18	7-26	8-10	8-16	
Mild mosaic	12	4	8	0	0	0	
Leaf roll	20	4	0	0	0	0	
Weather mottle	0	0	0	8	8	8	
Spindle tuber	0	0	0	12	0	0	
Giant hill	0	0	0	0	12	4	
1935*	7-3	7-10	7-17				
Mild mosaic	12	12	4				
1936*	7-15	7-22	7-29	8-6	8-14	8-21	
Mild mosaic	0	0	0	0	0	2	
Weather mottle	11	0	2	0	0	0	
Giant hill	0	0	0	0	0	12	
1937*	7-1	7-15	7-22	7-29	8-5	8-13	8-20
Mild mosaic	18	0	4	0	0	0	0
Leaf roll	20	4	0	0	0	0	0
Weather mottle	0	8	0	0	0	0	0

† Rogued by Geddes Simpson.
* Rogued by Wesley Porter.

TABLE 18

Aphid Population Counts—Spaulding—1933–1937

Year and [illegible]	First aphid record	First count											
		All forms						Winged forms					
		Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
1933 [illegible]		7-21	4	0-4	1.0	400 1	0.25	0	0	0	0	0	0
[illegible]													
M s	7-21		0	0	0	0	0	0	0	0	0	0	0
M p	7-21		0	0	0	0	0	0	0	0	0	0	0
A s	7-21		4	0-4	1.0	1	0.25	0	0	0	0	0	0
1934 [illegible]		7-4	3	0-1	1.0	288 3	1.04	1	0.3	33.33	0-1	1	0.3
[illegible]													
M s	7-26		0	0	0	0	0	0	0	0	0	0	0
M p	7-27		0	0	0	0	0	0	0	0	0	0	0
A s	7-4		3	0-1	1.0	3	1.04	1	0.3	33.33	0-1	1	0.3
1935 [illegible]		7-21	95	0-81	32.9	288 12	4.17	0	0	0	0	0	0
[illegible]													
M s	7-21		3	0-3	1.0	1	0.35	0	0	0	0	0	0
M p	7-21		1	0-1	0.3	1	0.35	0	0	0	0	0	0
A s	7-21		91	0-81	31.6	10	3.47	0	0	0	0	0	0
1936 [illegible]		7-9	1	0-1	0.5	180 1	0.55	0	0	0	0	0	0
[illegible]													
M s	7-21		1	0-1	0.5	1	0.55	0	0	0	0	0	0
M p	7-21		0	0	0	0	0	0	0	0	0	0	0
A s	7-21		0	0	0	0	0	0	0	0	0	0	0
1937 [illegible]		6-30	7	0-1	2.2	322 7	2.17	3	0.9	42.86	0-1	3	0.9
[illegible]													
M s	7-26		0	0	0	0	0	0	0	0	0	0	0
M p	7-26		0	0	0	0	0	0	0	0	0	0	0
A s	6-30		7	0-1	2.2	7	2.17	3	0.9	42.86	0-1	3	0.9

TABLE 19

Aphid Population Counts—Spaulding—1933–1937

Year and species	Second count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
3 (all spp.)	7-31	36	0-13	21.4	*182* 7	4.17	0	0	0	0	0	0
s		3	0-3	1.8	1	0.60	0	0	0	0	0	0
a		33	0-13	19.6	6	3.57	0	0	0	0	0	0
4 (all spp.)	7-13	31	0-15	10.0	*309* 6	1.94	0	0	0	0	0	0
s		12	0-5	3.8	4	1.29	0	0	0	0	0	0
a		19	0-15	6.1	2	0.65	0	0	0	0	0	0
5 (all spp.)	7-25	91	0-34	42.1	*216* 17	7.87	0	0	0	0	0	0
s		2	0-1	0.9	2	0.93	0	0	0	0	0	0
a		89	0-34	41.2	15	6.94	0	0	0	0	0	0
6 (all spp.)	7-21	7	0-3	3.2	*216* 3	1.39	0	0	0	0	0	0
s		7	0-3	3.2	3	1.39	0	0	0	0	0	0
7 (all spp.)	7-15	133	0-42	41.0	*324* 16	4.94	0	0	0	0	0	0
a		133	0-42	41.0	16	4.94	0	0	0	0	0	0

TABLE 20

Aphid Population Counts—Spaulding—1933–1937

Year and species	Third count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
1933 (all spp.)	8-11	226	0-23	132.2	*171* 52	30.41	6	3.5	2.65	0-1	6	3.5
M s		128	0-23	74.8	38	22.22	6	3.5	4.69	0-1	6	3.5
M p		6	0-4	3.5	2	1.17	0	0	0	0	0	0
A a		92	0-12	53.8	18	10.53	0	0	0	0	0	0
1934 (all spp.)	7-25	137	0-30	45.2	*303* 23	7.59	0	0	0	0	0	0
M s		3	0-1	1.0	3	0.99	0	0	0	0	0	0
M p		3	0-1	1.0	3	0.99	0	0	0	0	0	0
A a		131	0-30	43.2	17	5.61	0	0	0	0	0	0
1935 (all spp.)	8-8	1,121	0-215	461.3	*243* 70	28.81	1	0.4	0.09	0-1	1	0.41
M s		22	0-8	9.1	12	4.94	1	0.4	4.54	0-1	1	0.41
M p		21	0-8	8.6	7	2.88	0	0	0	0	0	0
A a		1,078	0-215	443.6	60	24.69	0	0	0	0	0	0
1936 (all spp.)	8-3	22	0-3	10.2	*216* 15	6.94	0	0	0	0	0	0
M s		22	0-3	10.2	15	6.94	0	0	0	0	0	0
1937 (all spp.)	7-29	45	0-9	13.9	*324* 19	5.86	0	0	0	0	0	0
M s		5	0-1	1.5	5	1.54	0	0	0	0	0	0
M p		7	0-1	2.2	7	2.16	0	0	0	0	0	0
A a		33	0-9	10.1	10	3.09	0	0	0	0	0	0

TABLE 21

Aphid Population Counts—Spaulding—1933–1937

Year and species	Fourth count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
3* (all spp.)	8-22	2,135	0-81	1,872.8	114 113	99.12	1	0.9	0.005	0-1	1	0.88
s		2,020	0-81	1,771.9	111	97.37	0	0	0	0	0	0
p		42	0-18	36.8	9	7.89	1	0.9	2.38	0-1	1	0.88
		73	0-30	64.0	3	2.63	0	0	0	0	0	0
(all spp.)	8-11	2,639	0-1,000	1,691.7	156 111	71.15	1	0.6	0.004	0-1	1	0.64
		74	0-6	47.4	38	24.36	0	0	0	0	0	0
		21	0-10	13.5	5	3.21	0	0	0	0	0	0
		2,544	0-1,000	1,630.8	95	60.90	1	0.6	0.004	0-1	1	0.64
(all spp.)	8-21	1,054	0-72	487.9	216 185	85.65	23	10.6	2.18	0-1	23	10.65
		804	0-35	372.2	170	78.70	20	9.3	2.49	0-1	20	9.26
		58	0-13	26.9	28	12.96	3	1.3	5.17	0-1	3	1.39
		192	0-72	88.8	20	9.26	0	0	0	0	0	0
(all spp.)	8-13	522	0-18	161.1	324 146	45.06	4	1.2	0.77	0-1	4	1.23
		57	0-5	17.6	30	9.26	2	0.6	3.51	0-1	2	0.62
		286	0-13	88.3	111	34.26	2	0.6	0.70	0-1	2	0.62
		179	0-18	55.2	40	12.35	0	0	0	0	0	0

*o bottom leaves remained on the plants at this time thus increasing the percentage of leaves infested to an abnormal figure.

TABLE 22

Aphid Population Counts—Spaulding—1934–1937

Year and species	Fifth count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
	8-21	No aphids remaining—foliage practically dead.										
(all spp.)	8-27	654	0-19	205.7	318 175	55.03	3	0.9	0.46	0-1	3	0.94
		98	0-4	30.8	70	22.01	2	0.6	2.04	0-1	2	0.63
		420	0-19	132.1	138	43.40	1	0.3	0.24	0-1	1	0.31
		136	0-13	42.8	42	13.21	0	0	0	0	0	0

TABLE 22—(Continued)

Arbitrary Population Classes—Spalding—1934–1937

Year and selection	Sixth count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or selected	Per cent re-tested	No.	Index	Per cent	Range	No. leaves re-tested	Per cent leaves re-tested
[illegible] (all segs.)	8-10	350	6-12	88.1	102	22.06	4	1.0	2.24	6-1	6	1
M 4		26	6-6	12.3	21	6.60	4	1.0	15.37	2-1	4	1
M 7		226	8-12	74.2	65	26.73	0	1.0	1.32	2-1	2	0
[illegible]		24	6-2	4.4	11	5.46	1	1.	0	0	0	0

TABLE 23

Date of Ripening and Infection of Hills Adjacent to Mosaic Hills Removed
Spalding—1932–1936

[illegible]	7-4	7-11	7-18	7-25
Total number of tubers harvested from hills adjacent to hills removed	345 (9 hills)	360 (9 hills)	285 (9 hills)	35 (1 hills)
Total number of tubers producing mosaic plants in 1933	12	4	0	1
1934	7-11	7-16	8-6	
Total number of tubers harvested from hills adjacent to hills removed	119 (9 hills)	135 (9 hills)	121 (9 hills)	
Total number of tubers producing mosaic plants in 1934	0	4	2	
1935	7-4	7-12	7-25	
Total number of tubers harvested from hills adjacent to hills removed	178 (9 hills)	45 (9 hills)	85 (11 hills)	
Total number of tubers producing mosaic plants in 1935	20	5	1	
1936	7-1	7-13	7-27	
Total number of tubers harvested from hills adjacent to hills removed	87 (9 hills)	121 (9 hills)	90 (9 hills)	
Total number of tubers producing mosaic plants in 1936	0	0	0	
1937	8-21			
Total number of tubers harvested from hills adjacent to hills removed	288 (9 hills)			
Total number of tubers producing mosaic plants in 1937	0			

TABLE 24

Date of Planting, Size of Plot and Diseased Hills Removed from Seed Plots Rogued at Woodland, 1934–1935

Year	Date of planting	Total hills in plot	Mild mosaic		Leaf roll		Yellow top		Weather mottle		Spindle tuber		Giant hill		Blackleg	
			Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed
1934	5-18	23,520	824	3.5	104	0.4	12	0.05	24	0.1	20	0.1	104	0.4	3	trace
1935	5-20	3,200	30	0.94	0	0	0	0	3	0.1	0	0	0	0	0	0
1936			Counts in commercial field before roguing gave: Mosaic 1.5 per cent, Leaf roll 0.08 per cent.													

TABLE 25

Diseased Hills Removed and Dates of Roguing—Woodland, 1934–1935

Year and disease	Hills removed because of various diseases on different dates						
1934*	7-4	7-12	7-18	7-26	8-7	8-9	8-16
Mosaic	136	44	0	16	72	476	80
Leaf roll	60	44	0	0	0	0	0
Yellow top	0	0	12	0	0	0	0
Weather mottle	0	0	16	8	0	0	0
Spindle tuber	0	0	16	4	0	0	0
Giant hill	0	0	0	0	12	0	92
Blackleg	0	1	1	0	1	0	0
1935*	7-2	7-9	7-16	7-23	8-6	8-14	
Mosaic	24	5	0	0	1	0	
Weather mottle	0	0	1	2	0	0	
1936†	Reading in commercial field before roguing: Mosaic 1.5 per cent; Leaf roll 0.08 per cent.						

* Rogued by Wesley Porter.
† Reading made by Geddes Simpson.

TABLE 26

Aphid Population Counts—Woodland—1934–1935

Year and species	First aphid record	First count											
		All forms						Winged forms					
		Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
1934 (all spp.)		7-4	643	0-78	99.7	645 144	22.33	17	2.6	2.64	0-2	16	2.48
M s	7-24		0	0	0	0	0	0	0	0	0	0	0
M p	7-24		0	0	0	0	0	0	0	0	0	0	0
A a	7-4		643	0-78	99.7	144	22.33	17	2.6	2.64	0-2	16	2.48
1935 (all spp.)		7-13	11	0-10	3.1	360 2	0.56	0	0	0	0	0	0
M s	8-7		0	0	0	0	0	0	0	0	0	0	0
A a	7-13		11	0-10	3.1	2	0.56	0	0	0	0	0	0

TABLE 26—(Continued)

Aphid Population Counts—Woodland—1934–1935

Year and species	Second count												
	All forms						Winged forms						
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
(all spp.)	7-13	2,436	0-175	425.1	*573* 175	30.54	2	0.3	0.01	0-1	2	0.35
		2,436	0-175	425.1	175	30.54	2	0.3	0.01	0-1	2	0.35
(all spp.)	7-25	46	0-30	12.7	*360* 7	1.94	0	0	0	0	0	0
		46	0-30	12.7	7	1.94	0	0	0	0	0	0

TABLE 27

Aphid Population Counts—Woodland—1934–1935

Year and species	Third count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
(all spp.)	7-24	8,782	0-500	1,626.3	*540* 302	55.93	2	0.4	0.02	0-1	2	0.37
		4	0-3	0.8	2	0.37	0	0	0	0	0	0
		2	0-1	0.4	2	0.37	0	0	0	0	0	0
		8,776	0-500	1,625.2	301	55.74	2	0.4	0.02	0-1	2	0.37
(all spp.)	8-7	457	0-83	126.9	*360* 51	14.17	1	0.3	0.22	0-1	1	0.28
		12	0-4	3.3	7	1.94	1	0.3	8.33	0-1	1	0.28
		445	0-83	123.6	46	12.77	0	0	0	0	0	0

Year and species	Fourth count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
all spp.)	8-6	?	0-?	very high	*522* 487	93.30	53	10.2	?	0-4	30	5.75
		10	0-4	1.9	7	1.34	0	0	0	0	0	0
		?*	0-1500±	very high	486	93.10	53	10.2	?	0-4	30	5.75
	8-21	Foliage largely destroyed (late blight). No count possible (Alate buckthorn and potato aphids observed).										

* infestation was so heavy that it was physically impossible to make a count. Many lower leaves were entirely covered with aphids. The average infestation of several leaves counted was 1500 aphids per leaf.

TABLE 28

Date of Roguing and Infection of Hills Adjacent to Mosaic Hills Removed Woodland—1934–1935

1934	7-4	7-12	7-18	7-26	8-9	8-16
Total number of tubers harvested from hills adjacent to units removed	140 (20 hills)	102 (20 hills)	60 (8 hills)	117 (20 hills)	118 (20 hills)	86 (8 hills)
Total number of tubers producing mosaic plants in 1935	21	24	2	3	11	33
1935	**7-2**	**7-9**	**7-23**	**8-6**		
Total number of tubers harvested from hills adjacent to units removed	291 (40 hills)	137 (30 hills)	45 (10 hills)	29 (10 hills)		
Total number of tubers producing mosaic plants in 1936	1	2	0	1		

TABLE 29

Date of Planting, Size of Plot and Diseased Hills Removed from Seed Plots Rogued at Smyrna Mills—1933—1934

Year	Date of planting	Total number of hills in plot	Mild mosaic		Leaf roll	
			Hills removed	Per cent removed	Hills removed	Per cent removed
1933	6-5	10,888	592	5.4	52	0.5
1934	6-3	4,112	236	5.7	32	0.8
1935	Counts made before roguing in a field planted with seed from the 1934 seed plot: 8 per cent mosaic; 0.1 per cent leaf roll.					

TABLE 30

Diseased Hills Removed and Dates of Roguing—Smyrna Mills—1933–1934

Year and disease	Hills removed because of various diseases on different dates				
1933*	7-10	7-18	7-28	8-5	8-15
Mild mosaic	344	144	76	20	8
Leaf roll	28	12	4	4	4
1934*	7-14	7-21	8-4	8-14	8-20
Mild mosaic	72	64	16	28	56
Leaf roll	24	8	0	0	0

* Rogued by Wesley Porter.

TABLE 31

Aphid Population Counts—Smyrna Mills—1933–1934

Year and species	First aphid record	First count											
		All forms						Winged forms					
		Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
(all spp.)		7-10	0	0	0	*150* 0	0	0	0	0	0	0	0
	8-2		0	0	0	0	0	0	0	0	0	0	0
	8-2		0	0	0	0	0	0	0	0	0	0	0
	8-2		0	0	0	0	0	0	0	0	0	0	0
(all spp.)		7-12	5	0-5	1.3	*372* 1	0.27	0	0	0	0	0	0
	7-23		0	0	0	0	0	0	0	0	0	0	0
	7-23		0	0	0	0	0	0	0	0	0	0	0
	7-12		5	0-5	1.3	1	0.27	0	0	0	0	0	0

Year and species	Second count												
	All forms						Winged forms						
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
	7-24	0	0	0	*147* 0	0	0	0	0	0	0	0
(all spp.)	7-23	14	0-5	3.2	*432* 5	1.16	0	0	0	0	0	0
		2	0-2	0.5	1	0.23	0	0	0	0	0	0
		1	0-1	0.3	1	0.23	0	0	0	0	0	0
		11	0-5	2.5	3	0.69	0	0	0	0	0	0

TABLE 32

Aphid Population Counts—Smyrna Mills—1933–1934

Year and species	Third count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	
[illegible] (all spp.)	8-2	5	0-2	1.4	348 4	1.15	1	0.3	20.00	0-1	1	
M s		1	0-1	0.3	1	0.29	0	0	0	0	0	
M p		2	0-2	0.6	1	0.29	0	0	0	0	0	
A a		2	0-1	0.6	2	0.57	1	0.3	50.00	0-1	1	
[illegible] (all spp.)	8-4	180	0-49	45.5	396 29	7.32	1	0.3	0.55	0-1	1	
M s		9	0-2	2.3	7	1.77	0	0	0	0	0	
M p		18	0-14	4.5	5	1.26	0	0	0	0	0	
A a		153	0-49	38.6	18	4.55	1	0.3	0.65	0-1	1	

Year and species	Fourth count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	
[illegible] (all spp.)	8-15	541	0-44	163.9	330 150	45.45	27	8.2	4.99	0-2	23	
M s		429	0-44	130.0	120	36.36	15	4.5	3.50	0-2	14	
M p		111	0-16	33.6	34	10.30	12	3.6	10.81	0-2	11	
A a		1	0-1	0.3	1	0.30	0	0	0	0	0	

TABLE 33

Date of Rogueing and Infection of Hills Adjacent to Mosaic Hills Removed Smyrna Mills—1933–1934

1933	7-10	7-18	7-29	8-5	8-15	
Total number of tubers harvested from hills adjacent to units removed	117 (20 hills)	122 (20 hills)	110 (20 hills)	94 (20 hills)	81 (15 hills)	
Total number of tubers producing mosaic plants in 1934	9	5	6	1	6	
1934	7-14	7-20	7-25	8-4	8-14	8-20
Total number of tubers harvested from hills adjacent to units removed	136 (20 hills)	69 (10 hills)	63 (10 hills)	197 (30 hills)	68 (10 hills)	66 (10 hills)
Total number of tubers producing mosaic plants in 1935	11	9	15	13	21	2

TABLE 34

Date of Planting, Size of Plot and Diseased Hills Removed from Seed Plots Rogued at Benedicta, 1931–1934

Year	Date of planting	Total hills in plot	Mosaic		Leaf roll		Giant hill		Verticillium wilt	
			Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed
1931	5-15	26,880	84	0.3	60	0.2	0	0	0	0
1932	5-19	16,424	48	0.3	28	0.17	96	0.6	0	0
1933	5-7	13,876	16	0.11	8	0.05	?	?	0	0
1934	5-10	15,832	0	0	16	0.13	16	0.13	15	0.09

TABLE 35

Diseased Hills Removed and Dates of Roguing—Benedicta—1931–1934

Year and disease	Hills removed on different dates because of disease						
1931*	7-3°	7-9	7-15	7-23	7-30		
Mosaic	48	24	4	8	0		
Leaf roll	0	32	12	0	16		
1932*	7-5	7-7	7-12	7-18	7-26	8-3	8-20
Mosaic	0	4	32	4	0	4	0
Leaf roll	0	8	16	0	4	0	0
Weather mottle	4	0	28	0	4	0	0
Giant hill	0	0	0	0	0	0	96
1933†	7-3	7-5	7-16	7-24	8-1		
Mosaic	4	8	0	4	0		
Leaf roll	8	0	0	0	0		
Giant hill	0	0	0	0	0		
1934†	6-29*	7-2	7-9	7-23	7-30	8-9	
Mosaic	0	0	0	0	0	0	
Leaf roll	12	4	0	0	0	0	
Giant hill	0	0	0	0	0	16	
Verticillium wilt	0	0	0	5	0	10	

* Rogued by Ralph Robinson and Geddes Simpson.
° Rogued by Donald Folsom.
† Rogued by Wesley Porter.

TABLE 36

Aphid Population Counts—Benedicta—1931–1934

Year and species	First aphid record	First count											
		All forms						Winged forms					
		Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	
1931 (all spp.)		No detailed counts were made in this plot in 1931											
M s	7-3												
M p	7-15												
1932 (all spp.)		8-3	536	0-48	446.7	*120* 92	76.66	3	2.5	0.56	0-1	3	
M s	7-5		536	0-48	446.7	92	76.66	3	2.5	0.56	0-1	3	
M p	7-26		0	0	0	0	0	0	0	0	0	0	
A a	8-15		0	0	0	0	0	0	0	0	0	0	
1933 (all spp.)		7-10	0	0	0	*360+* 0	0	0	0	0	0	0	
M s	7-15		0	0	0	0	0	0	0	0	0	0	
M p	8-2		0	0	0	0	0	0	0	0	0	0	
A a	7-23		0	0	0	0	0	0	0	0	0	0	
1934 (all spp.)		7-2	15	0-6	3.0	*507* 10	1.97	1	0.2	6.67	0-1	1	
M s	7-2		7	0-2	1.4	7	1.38	1	0.2	14.30	0-1	1	
M p	7-24		0	0	0	0	0	0	0	0	0	0	
M ps*	7-2		1	0-1	0.2	1	0.2	0	0	0	0	0	
A a	7-2		7	0-6	1.4	2	0.39	0	0	0	0	0	

* *Myzus pseudosolani* Theob.. the foxglove aphid.

TABLE 37

Aphid Population Counts—Benedicta—1932–1934

Year and species	Second count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
					108							
(all spp.)	8-15	190	0-17	175.9	54	50.00	7	6.5	3.86	0-1	7	6.48
		104	0-9	96.3	46	42.59	6	5.6	5.77	0-1	6	5.60
		81	0-17	75.0	16	14.81	1	1.0	1.23	0-1	1	0.93
		5	0-2	4.6	3	2.78	0	0	0	0	0	0
					100							
	7-15	3	0-1	3.0	3	3.00	0	0	0	0	0	0
		3	0-1	3.0	3	3.00	0	0	0	0	0	0
					189							
(all spp.)	7-11	54	0-20	28.6	11	5.82	0	0	0	0	0	0
		2	0-1	1.1	2	1.06	0	0	0	0	0	0
		4	0-3	2.1	2	1.06	0	0	0	0	0	0
		48	0-20	25.4	8	4.23	0	0	0	0	0	0

Year and species	Third count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
					246							
(all spp.)	7-23	99	0-17	40.3	30	12.19	0	0	0	0	0	0
		20	0-4	8.2	16	6.50	0	0	0	0	0	0
		79	0-17	32.1	18	7.32	0	0	0	0	0	0
					486							
(all spp.)	7-22	220	0-15	45.2	63	12.96	1	0.2	0.45	0-1	1	0.21
		23	0-2	4.8	19	3.91	1	0.2	4.35	0-1	1	0.21
		1	0-1	0.2	1	0.21	0	0	0	0	0	0
		25	0-5	5.2	11	2.26	0	0	0	0	0	0
		171	0-15	35.2	38	7.82	0	0	0	0	0	0

TABLE 38

Aphid Population Counts—Benedicta—1933–1934

Year and species	Fourth count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
					267							
1933 (all spp.)	8-2	290	0-19	108.6	87	32.58	2	0.7	0.70	0-1	2	
M s		155	0-15	58.1	62	23.22	2	0.7	1.29	0-1	2	
M p		129	0-19	48.3	34	12.73	0	0	0	0	0	
A a		6	0-6	2.2	1	0.37	0	0	0	0	0	
					111							
1934 (all spp.)	8-4	932	0-150	839.6	69	62.16	8	7.2	0.90	0-1	8	
M s		73	0-11	66.0	28	25.22	7	6.3	9.60	0-1	7	
M p		50	0-10	45.0	14	12.61	1	0.9	2.00	0-1	1	
M ps		72	0-14	65.0	17	15.32	0	0	0	0	0	
A a		737	0-150	664.0	43	38.73	0	0	0	0	0	

Year and species	Fifth count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
					42							
1933 (all spp.)	8-12	217	0-66	516.7	31	73.80	2	4.8	0.92	0-1	2	
M s		48	0-12	114.3	20	47.61	2	4.8	4.17	0-1	2	
M p		163	0-66	388.1	15	35.71	0	0	0	0	0	
A a		6	0-3	14.3	3	7.14	0	0	0	0	0	

Year and species	Sixth count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
					81							
1933 (all spp.)	8-18	568	0-78	701.2	64	79.01	10	12.3	1.76	0-3	7	
M s		243	0-25	300.0	48	59.26	10	12.3	4.12	0-3	7	
M p		245	0-40	302.5	29	35.80	0	0	0	0	0	
A a		80	0-78	98.8	2	2.47	0	0	0	0	0	

TABLE 39

Date of Roguing and Infection of Hills Adjacent to Mosaic Hills Removed Benedicta—1931–1934

1931	7-3	7-9	7-15	7-23
Total number of tubers harvested from hills adjacent to units removed	116 (20 hills)	107 (20 hills)	112 (20 hills)	64 (10 hills)
Total number of tubers producing mosaic plants in 1932	1	4	0	2
1932	7-7	7-12	7-18	8-3
Total number of tubers harvested from hills adjacent to units removed	76 (10 hills)	129 (20 hills)	69 (10 hills)	100 (10 hills)
Total number of tubers producing mosaic plants in 1933	0	0	0	0
1933	7-5	7-24		
Total number of tubers harvested from hills adjacent to units removed	209 (20 hills)	105 (10 hills)		
Total number of tubers producing mosaic plants in 1934	0	0		
1934	No mosaic plants removed from the plot			

TABLE 40

Date of Planting, Size of Plot and Diseased Hills Removed from Seed Plots Rogued at Masardis, 1931–1933

Year	Date of planting	Total hills in plot	Mild mosaic		Leaf roll		Weather mottle	
			Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed
1931	6-9	11,600	4	0.04	20	0.17	0	0
1932	6-7	6,212	40	0.6	12	0.19	12	0.19
1933	6-2	31,732	184	0.6	216	0.7	0	0

TABLE 41

Date of Planting, Size of Plot and Diseased Hills Removed from Seed Plots Rogued Masardis, 1933–1938

Year	Date of planting	Total hills in plots	Mild mosaic		Leaf roll		Weather mottle		Giant hill		Apical leaf roll		Verticillium wilt	
			Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	Per cent removed	Hills removed	P ce r
1933	6-2	32,144	28	0.08	60	0.19	0	0	0	0	0	0	0	0
1934	{5-14 {5-31	18,740	0	0	34	0.18	0	0	6	0.03	0	0	7	0.
1935	5-16	38,000	20	0.05	4	0.01	9	0.02	4	0.01	0	0	4	0.
1936	5-14	35,450	0	0	0	0	46	0.13	20	0.06	0	0	0	0
1937	5-15	48,600	0	0	0	0	0	0	0	0	4	0.01	15	0.
1938	5-7	42,800	15	0.03	74	0.17	16	0.03	16	0.03	0	0	0	0

TABLE 42

Diseased Hills Removed and Dates of Roguing—Masardis—1931–1938

Year and disease	Hills rogued for various diseases on different dates								
1931*	7-8‡	7-13	7-21‡	7-29	8-12				
Mosaic	1	0	0	0	0				
Leaf roll	3	1	0	1	0				
1932*	7-9	7-15	7-23	8-2	8-14	8-26			
Mosaic	1	8	0	1	0	0			
Leaf roll	0	0	3	0	0	0			
Weather mottle	1	1	1	0	0	0			
1933°	7-12	7-21	7-26	8-2	8-12				
Mosaic	0	2	2	5	0				
Leaf roll	1	13	1	0	0				
1934°	7-12	7-17	7-24	7-31	8-14	8-17			
Mosaic	0	0	0	0	0	0			
Leaf roll	16	18	0	0	0	0			
Giant hill	0	0	0	0	6	0			
Verticillium wilt	0	0	0	0	3	3			
1935°	7-1	7-8	7-15	7-22	7-29	8-2	8-5	8-12	
Mosaic	20	0	0	0	0	0	0	0	
Leaf roll	4	0	0	0	0	0	0	0	
Weather mottle	0	0	7	2	0	0	0	0	
Giant hill	0	0	0	0	4	0	0	0	
Verticillium wilt	0	0	0	0	0	4	0	0	
1936°	7-7	7-14	7-21	7-28	8-4	8-12	8-19		
Mosaic	0	0	0	0	0	0	0		
Leaf roll	0	0	0	0	0	0	0		
Weather mottle	4	30	12	0	0	0	0		
Giant hill	0	0	0	0	0	12	8		
1937°	7-2§	7-14	7-20	7-27	8-3	8-12	8-23		
Mosaic	0	0	0	0	0	0	0		
Leaf roll	0	0	0	0	0	0	0		
Weak hills	16	0	0	0	0	0	0		
Faint mottle	12	0	0	0	0	0	0		
Giant hill?	0	0	0	0	0	8	0		
Apical leaf roll	0	0	0	0	0	4	0		
Verticillium wilt	0	0	0	5	10	0	0		
1938°	6-22†	6-28†	7-6	7-13	7-20	7-28	8-4	8-11	8-18
Mosaic	0	0	4	0	11	0	0	0	0
Leaf roll	28	40	6	0	0	0	0	0	0
Weather mottle	0	0	16	6	0	0	0	0	0
Weak hills	0	0	0	0	0	0	0	0	0
Giant hill?	0	0	0	0	0	16	0	0	0
Faint mottle	0	0	0	0	0	0	0	0	0
Apical leaf roll	0	0	0	0	0	0	0	0	0
Verticillium wilt	0	0	0	0	0	0	0	0	0

* Rogued by Harry Allen and Geddes Simpson.
‡ Rogued by Donald Folsom.
° Rogued by Wesley Porter.
§ Rogued by Reiner Bonde and Geddes Simpson.
† Rogued by Walter Raleigh and Geddes Simpson.

TABLE 43

Aphid Population Counts—Masardis—1931–1937

Year and species	First aphid record	First count												
		All forms						Winged forms						
		Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
1931		7-8	1	0	0	294							
M s	7-21		0	0	0	0	0	0	0	0	0	0	0
A a	7-21		0	0	0	0	0	0	0	0	0	0	0
1932 (all spp.)		8-6	450	0-20	105.4	210							
M s	7-18		427	0-20	148.1	80	46.20	0	0	0	0	0	0
M p	7-18		20	0-2	4.2	74	16.67	0	0	0	0	0	0
A a	7-25		24	0-12	11.1	7	2.24	0	0	0	0	0	0
						5	1.85	0	0	0	0	0	0
1933 (all spp.)		7-21	0	0	0	126							
M s	7-21		0	0	0	0	0	0	0	0	0	0	0
M p	7-21		0	0	0	0	0	0	0	0	0	0	0
A a	7-21		0	0	0	0	0	0	0	0	0	0	0
1934 (all spp.)		7-6	37	0-14	15.8	176							
M s	7-6		2	0-2	1.1	8	4.55	2	1.1	7.41	0-1	2	1.1
M ps	7-6		2	0-1	1.1	1	0.57	0	0	0	0	0	0
A a	7-6		33	0-14	14.1	2	1.14	0	0	0	0	0	0
						5	2.84	2	1.1	8.70	0-1	2	1.1
1935		7-8	0	0	0	282							
M s	7-15		0	0	0	0	0	0	0	0	0	0	0
M p	7-22		0	0	0	0	0	0	0	0	0	0	0
A a	7-15		0	0	0	0	0	0	0	0	0	0	0
						0	0	0	0	0	0	0	0
1936		7-6	4	0-3	0.9	426							
M s	7-6		4	0-3	0.9	2	0.47	0	0	0	0	0	0
M p	7-22		0	0	0	2	0.47	0	0	0	0	0	0
A a	7-14		0	0	0	0	0	0	0	0	0	0	0
						0	0	0	0	0	0	0	0
1937		7-2	4	0-1	1.3	300							
M s	7-27		0	0	0	4	1.33	3	1	75.00	0-1	3	1.0
M p	7-13		0	0	0	0	0	0	0	0	0	0	0
A a	7-2		4	0-1	1.3	0	0	0	0	0	0	0	0
						4	1.33	3	1	75.00	0-1	3	1.0

TABLE 44

Aphid Population Counts—Masardis—1931–1937

Year and species	Second count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
31	7-13	0	0	0	1700±[1] 0	0	0	0	0	0	0	0
32 (all spp.)	8-13	1,809	0-124	837.5	776 157	72.68	49	22.7	2.71	0-3	33	15.28
s		1,749	0-124	809.7	149	68.98	49	22.7	2.80	0-3	33	15.28
p		56	0-14	25.9	9	4.16	0	0	0	0	0	0
a		4	0-2	1.9	3	1.38	0	0	0	0	0	0
33 (all spp.)	7-31	53	0-29	14.4	366 5	1.37	0	0	0	0	0	0
s		2	0-1	0.6	2	0.55	0	0	0	0	0	0
a		51	0-29	13.9	3	0.82	0	0	0	0	0	0
34 (all spp.)	7-12	14	0-7	7.6	184 2	1.09	0	0	0	0	0	0
s		7	0-7	3.8	1	0.54	0	0	0	0	0	0
a		7	0-7	3.8	1	0.54	0	0	0	0	0	0
35 (all spp.)	7-15	38	0-24	6.9	549 4	0.73	0	0	0	0	0	0
s		1	0-1	0.2	1	0.18	0	0	0	0	0	0
a		37	0-24	6.7	3	0.55	0	0	0	0	0	0
36 (all spp.)	7-14	42	0-11	10.0	420 20	4.76	0	0	0	0	0	0
s		38	0-11	9.0	19	4.52	0	0	0	0	0	0
a		4	0-4	0.9	1	0.24	0	0	0	0	0	0
37 (all spp.)	7-13	6	0-3	2.0	300 3	1.00	1	0.3	16.66	0-1	1	0.33
s		1	0-1	0.3	1	0.33	0	0	0	0	0	0
a		5	0-3	1.7	2	0.66	1	0.3	20.00	0-1	1	0.33

[1] All leaves of plants taken from 32 hills in various parts of the seed plot were examined for aphids.

TABLE 45

Aphid Population Counts—Masardis—1931–1937

Year and species	Third count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
1931 (all spp.)	7-21	41	?	11.2	366	?	0	0	0	0	0	0
M s		19	?	5.2	?	?	0	0	0	0	0	0
A s		22	?	6.0	?	?	0	0	0	0	0	0
1932 (all spp.)	8-26	2,408	0-215	1,168.9	246	86.88	20	9.5	0.81	0-3	17	7.8
M s		2,244	0-215	946.3	185	85.64	18	8.3	0.88	0-3	15	6.9
M p		206	0-18	56.4	46	21.29	0	0	0	0	0	0
A a		226	0-49	97.2	27	12.50	2	1.0	0.85	0-1	2	0.9
1933 (all spp.)	8-11	857	0-221	166.3	246	10.71	5	1.5	1.49	0-1	5	1.5
M s		55	0-8	16.4	24	7.14	3	0.9	5.45	0-1	3	0.8
M p		25	0-12	7.4	7	2.08	2	0.6	8.00	0-1	2	0.6
A a		277	0-221	82.4	7	2.08	0	0	0	0	0	0
1934 (all spp.)	7-23	17	0-6	10.1	168	4.76	0	0	0	0	0	0
M s		7	0-3	4.2	3	1.79	0	0	0	0	0	0
A s		20	0-6	6.0	5	2.98	0	0	0	0	0	0
1935 (all spp.)	7-22	745	0-154	138.5	528	4.46	0	0	0	0	0	0
M p		6	0-6	1.1	24	0.15	0	0	0	0	0	0
A a		709	0-154	137.4	25	4.28	0	0	0	0	0	0
1936 (all spp.)	7-22	102	0-7	24.3	439	12.85	1	0.02	0.98	0-1	1	0.0
M s		92	0-7	21.9	56	12.69	1	0.02	1.09	0-1	1	0.0
M p		5	0-5	1.2	1	0.24	0	0	0	0	0	0
A a		5	0-4	1.2	2	0.48	0	0	0	0	0	0
1937 (all spp.)	7-27	12	0-3	4.0	300	3.33	0	0	0	0	0	0
M s		6	0-1	2.0	6	2.00	0	0	0	0	0	0
M p		2	0-1	0.7	2	0.66	0	0	0	0	0	0
A a		4	0-3	1.3	2	0.66	0	0	0	0	0	0

TABLE 46

Aphid Population Counts—Masardis—1931–1937

Year and species	Fourth count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Per cent leaves infested
31 s a	7-29	Present Present										
3 (all spp.) s p a	8-22	2,066 1,792 133 141	0-75 0-75 0-12 0-50	614.9 533.3 39.6 42.0	*336* 232 208 28 9	69.04 61.90 8.33 2.68	60 50 10 0	17.8 14.8 3.0 0	2.90 2.79 7.52 0	0-6 0-6 0-1 0	28 19 10 0	8.33 5.65 3.00 0
5 (all spp.) s p a	8-6	3,344 98 88 3,158	0-358 0-9 0-20 0-358	599.2 17.5 15.7 566.0	*558* 162 59 26 118	29.03 10.57 4.66 21.15	5 0 0 5	0.9 0 0 0.9	0.14 0 0 0.16	0-2 0 0 0-2	4 0 0 4	0.72 0 0 0.72
6 (all spp.) s p a	8-1	699 644 14 41	0-31 0-31 0-5 0-13	166.4 153.3 3.3 9.8	*420* 169 162 6 9	40.24 38.57 1.43 2.14	12 12 0 0	2.9 2.9 0 0	1.71 1.86 0 0	0-1 0-1 0 0	12 12 0 0	2.86 2.86 0 0
7 (all spp.) s p a	8-12	960 198 521 241	0-56 0-15 0-56 0-46	320.0 66.0 173.7 80.3	*300* 164 75 107 24	54.67 25.00 35.67 8.00	5 0 5 0	1.7 0 1.7 0	0.52 0 0.96 0	0-1 0 0-1 0	5 0 5 0	1.66 0 1.66 0

TABLE 47

Aphid Population Counts—Masardis—1935–1937

Year and species	Fifth count											
	All forms						Winged forms					
	Date	No.	Range	Index	No. leaves counted or infested	Per cent infested	No.	Index	Per cent	Range	No. leaves infested	Pe cen leav in fest
					561							
1935 (all spp.)	8-20	4,662	0-225	831.0	317	56.51	17	3.0	0.36	0-5	9	1
M s		333	0-13	59.4	125	22.28	4	0.7	1.20	0-1	4	0
M p		63	0-25	11.2	12	2.14	1	0.2	1.60	0-1	1	0
A a		4,266	0-225	760.4	267	47.59	12	2.1	0.28	0-5	4	0
					420							
1936 (all spp.)	8-20	3,161	0-547	752.6	310	73.81	83	19.8	2.63	0-8	56	13
M s		2,050	0-56	488.0	292	69.52	66	15.7	3.22	0-8	48	11
M p		343	0-38	81.6	58	13.81	5	1.2	1.46	0-1	5	1
A a		768	0-547	182.9	22	5.24	12	2.9	1.56	0-7	3	0
					300							
1937 (all spp.)	8-24	5,209	0-350	1,736.3	289	96.33	28	9.3	0.54	0-2	25	8
M s		2,078	0-45	692.6	239	79.67	7	2.3	0.34	0-2	6	2
M p		1,623	0-79	541.0	183	61.00	21	7.0	1.29	0-2	19	6
A a		1,508	0-350	502.7	32	10.67	0	0	0	0	0	0

TABLE 48

Date of Roguing and Infection of Hills Adjacent to Mosaic Hills Removed Masardis

1931	7-8	7-13	7-21	9-19*
Total number of tubers harvested from hills adjacent to units removed	212 (30 hills)	55 (10 hills)	201 (20 hills)	92 (24 hills)
Total number of tubers producing mosaic plants in 1932	3	0	9	2
1932	7-9	7-15	7-23	8-2
Total number of tubers harvested from hills adjacent to units removed	193 (20 hills)	185 (20 hills)	192 (20 hills)	185 (20 hills)
Total number of tubers producing mosaic plants in 1933	3	6	2	4
1933	7-20	7-26	8-2	8-12
Total number of tubers harvested from hills adjacent to units removed	159 (20 hills)	171 (20 hills)	94 (10 hills)	89 (10 hills)
Total number of tubers producing mosaic plants in 1934	0	0	2	4
1934	No mosaic removed			
1935	7-1			
Total number of tubers harvested from hills adjacent to units removed	356 (60 hills)			
Total number of tubers producing mosaic plants in 1936	6			
1936	No mosaic removed			
1937	No mosaic removed			

* Hills were not adjacent to mosaic hills removed.